Forensic Chemistry: Forensic Science from a Chemist's Perspective

Andria Pace

MacMillan Group Meeting

Literature Talk

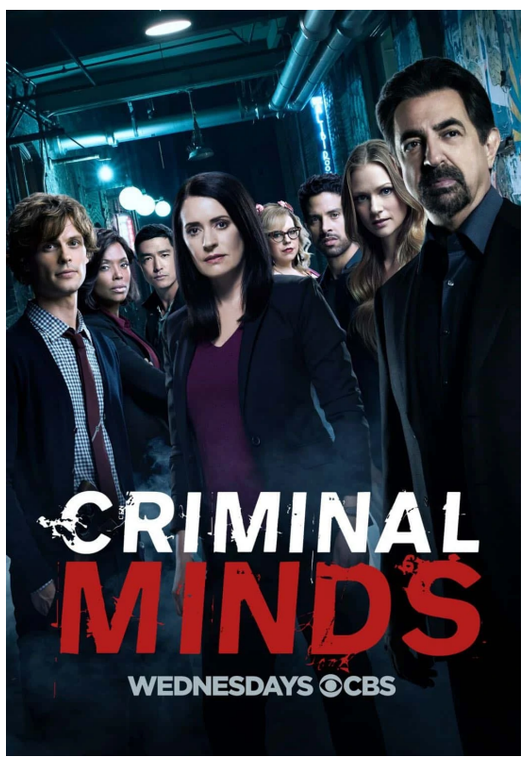
October 4, 2022

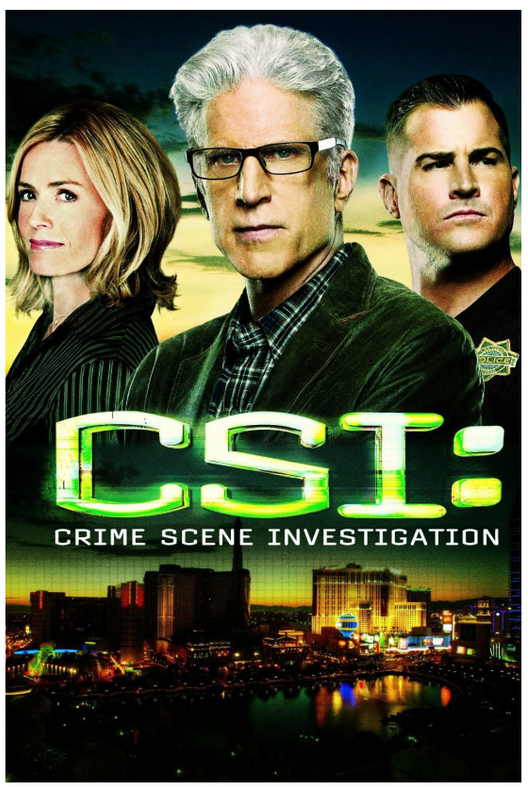
Forensic Chemistry: Forensic Science from a Chemist's Perspective

What do you think about when I say forensic chemistry?

Forensic Chemistry: Forensic Science from a Chemist's Perspective

What do you think about when I say forensic chemistry?





Forensic Chemistry: Forensic Science from a Chemist's Perspective

What do you think about when I say forensic chemistry?

What are your preconceived notions of forensic science?

What is Forensic Chemistry?

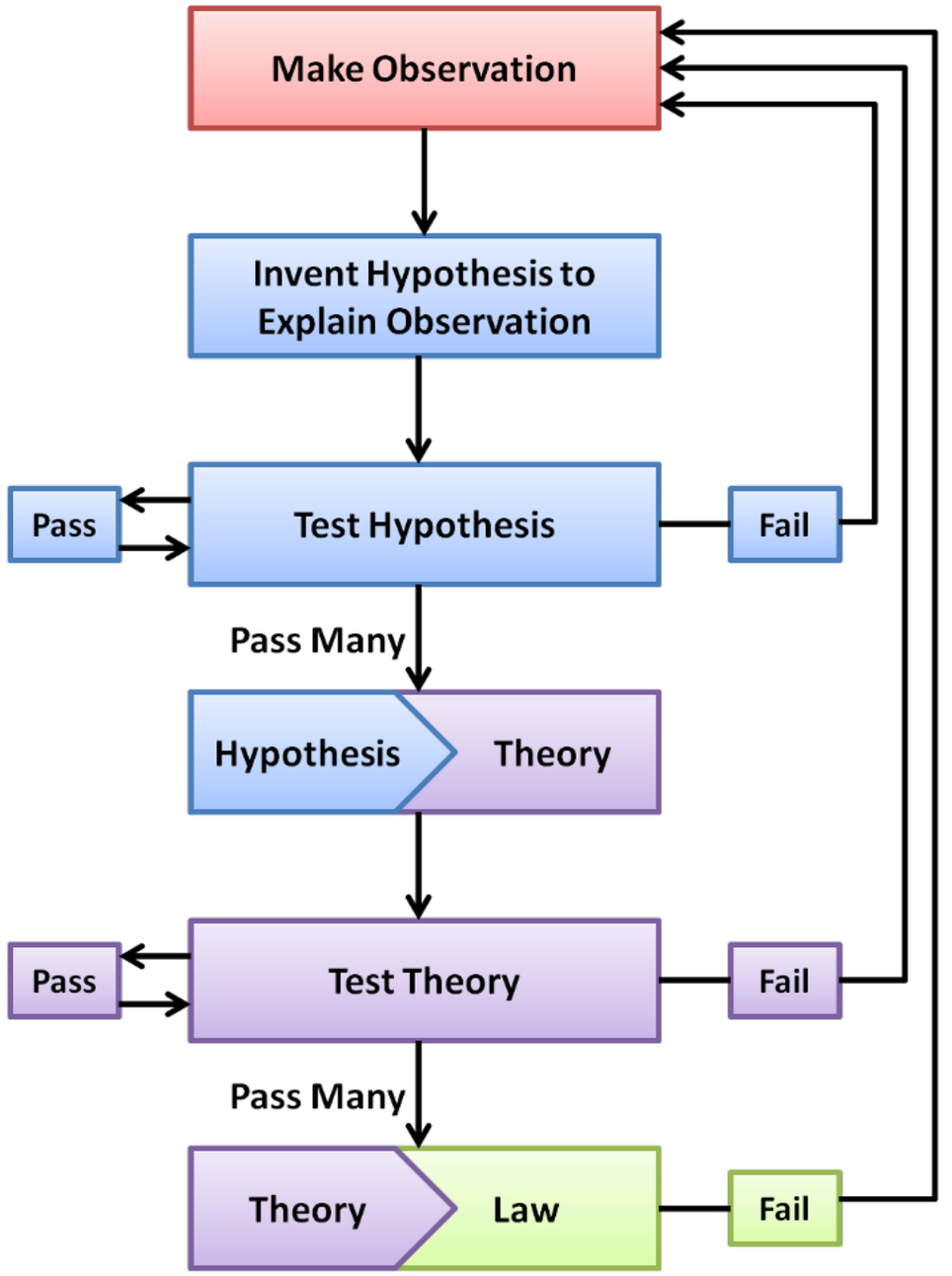
Forensic science: qualitative or quantitative science?

Malhi, R.; Hughes, C. (2020) *Forensic Science: History and Development*.

What is Forensic Chemistry?

Forensic science: qualitative or quantitative science?

interplay between science, medicine, and law



Malhi, R.; Hughes, C. (2020) *Forensic Science: History and Development*.

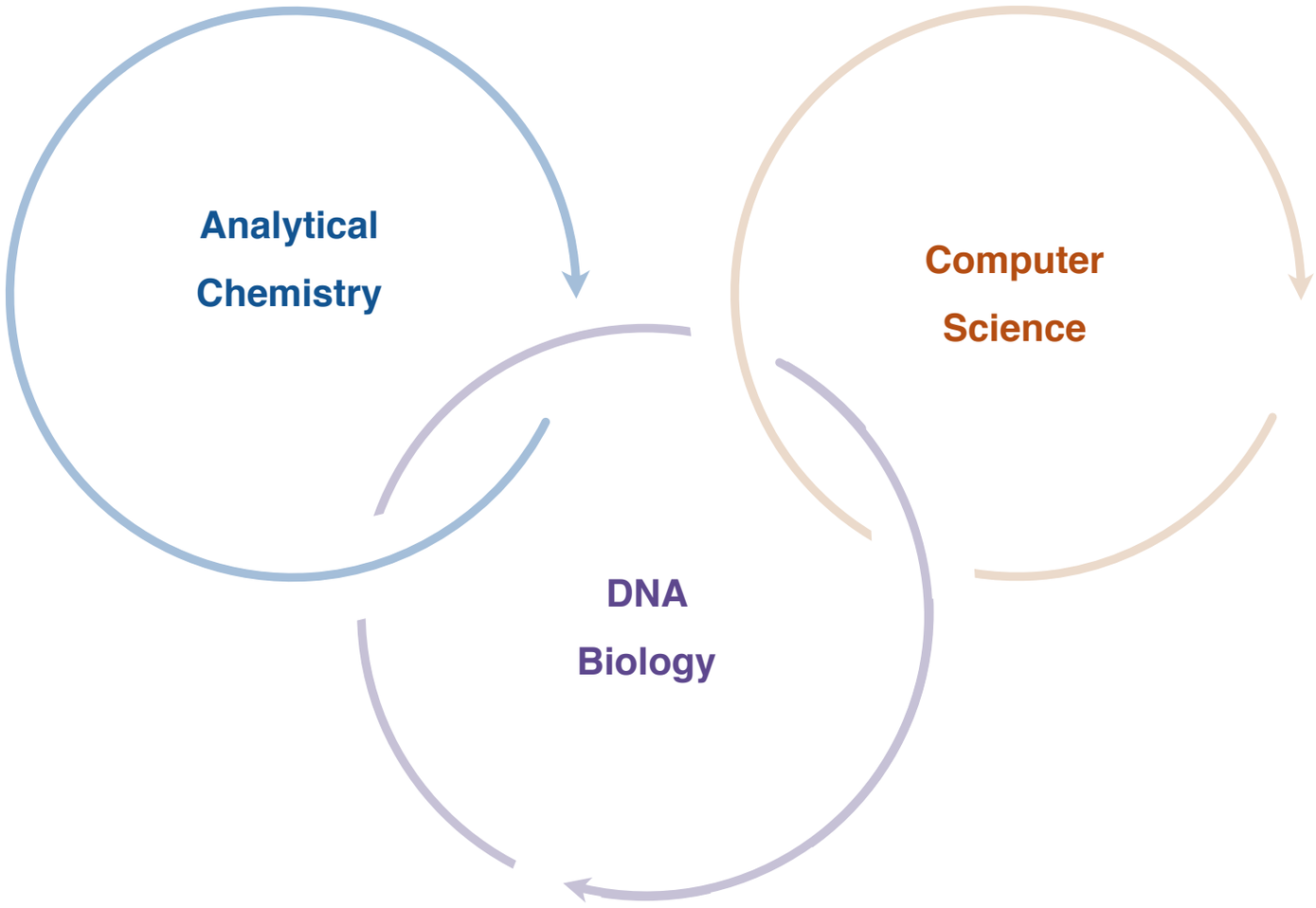
What is Forensic Chemistry?

Forensic Science

Social Sciences	Biological Sciences	Physical Sciences
Forensic Psychiatrists	*Forensic pathology*	*Forensic chemistry*
Forensic Psychologists	*Forensic anthropology*	*toxicology*
	Forensic genetics	*fiber, soil, paint, glass, explosives analysis*
	Bloodstain pattern analysis	*fingerprint examination*
	Forensic entomology	

Malhi, R.; Hughes, C. (2020) *CSI: Securing, Recording, and Analyzing Evidence*.

What is Forensic Chemistry?



Forensic science is really the combination of many disciplines!

Malhi, R.; Hughes, C. (2020) *Forensic Science: History and Development*.

Forensic Chemistry: a timeline of the field

Alphonse Bertillon

- French criminologist and anthropologist
- founder of the Bertillion system: 20 measurements for identification
- coined the concept of anthropometry: the first rudimentary forensic ‘database’
- implemented a systematic method for photographing crime scenes

1879

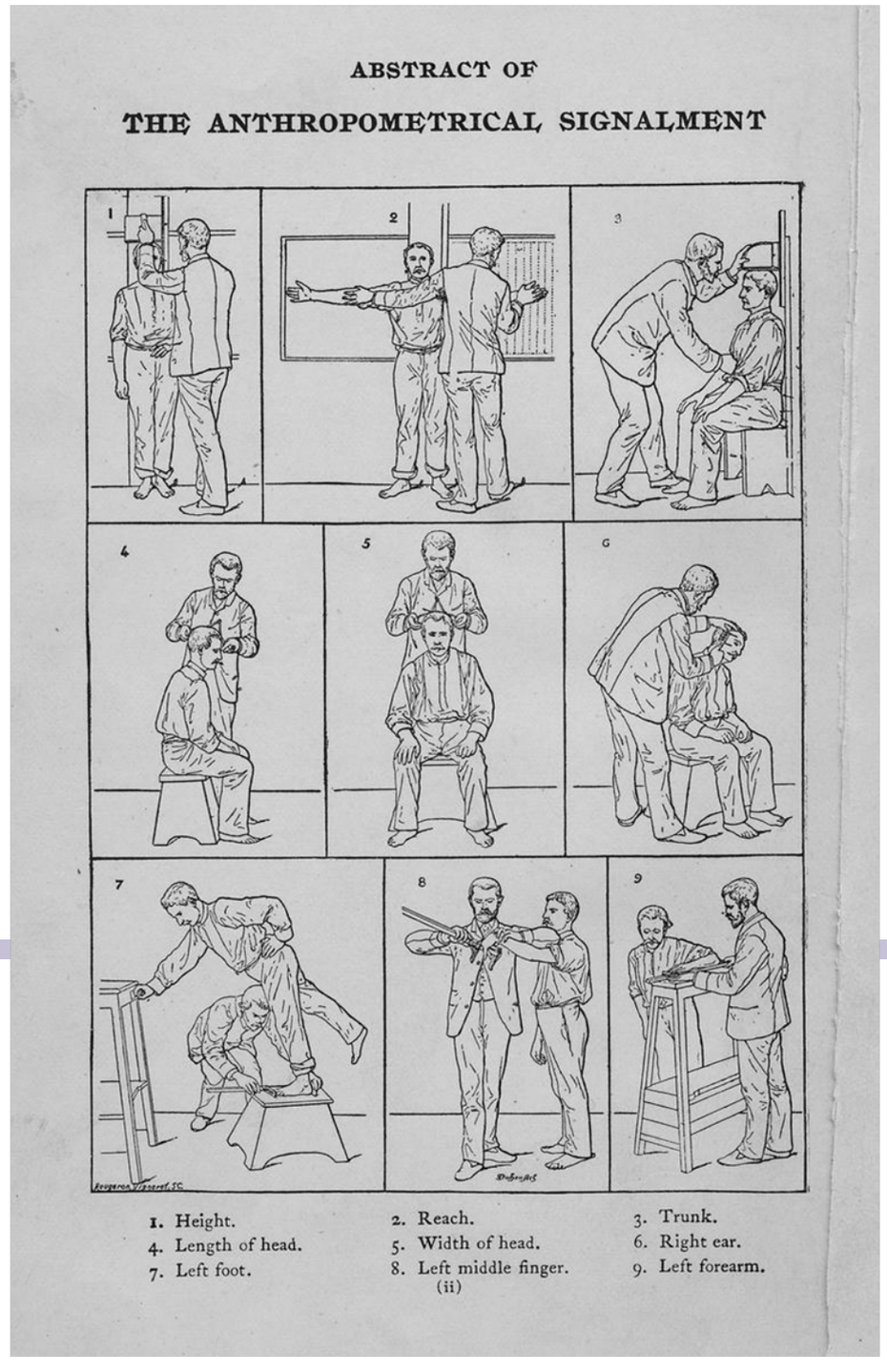
Malhi, R.; Hughes, C. (2020) *Forensic Science: History and Development*.

Forensic Chemistry: a timeline of the field

Based on the assumption that no 2 individuals are alike

Alphonse Bertillon

1879



Is this actually true?

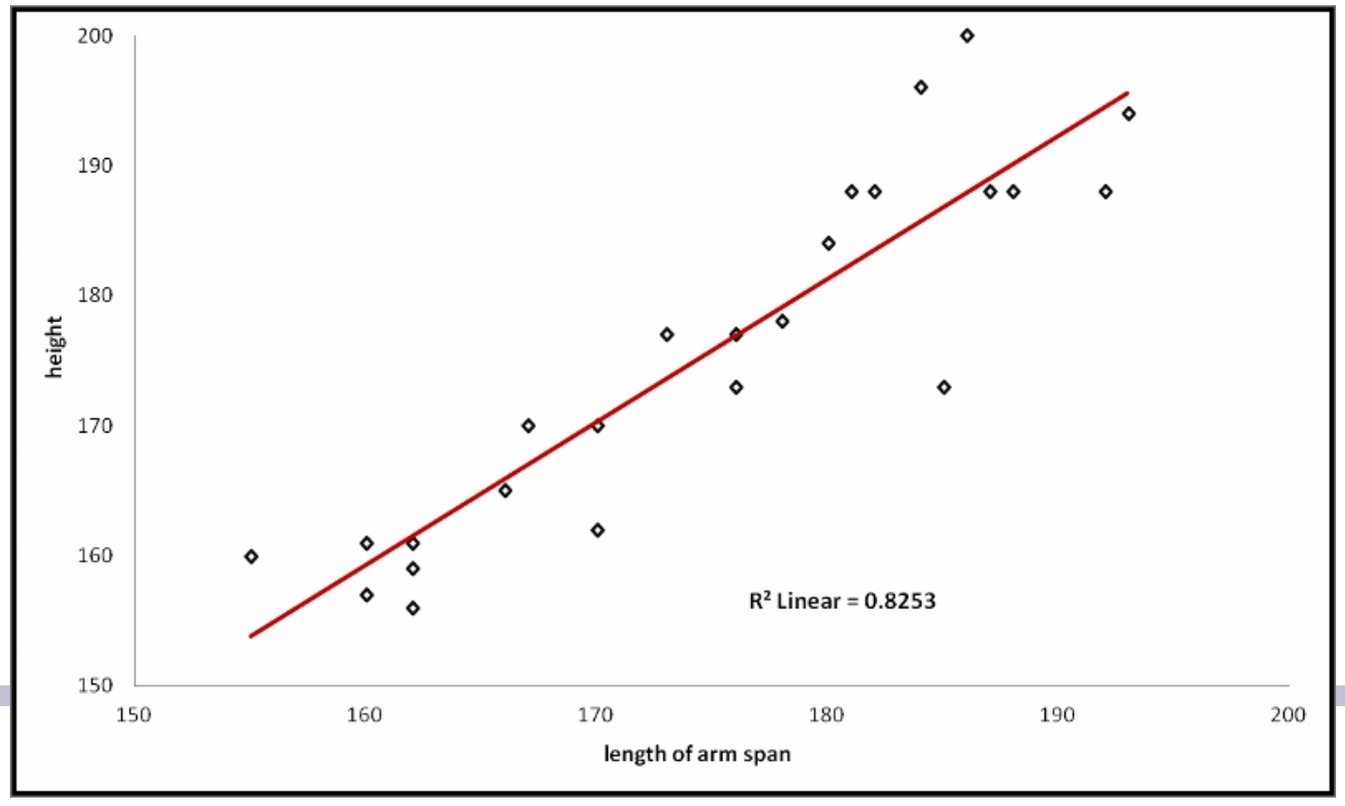
Malhi, R.; Hughes, C. (2020) *Forensic Science: History and Development*.

Forensic Chemistry: a timeline of the field

Based on the assumption that no 2 individuals are alike

- to gain statistically significant data, there must be no correlation between any of the measurements used

Alphonse Bertillon



1879

by the mid 1880's this theory was already being brought into question

Malhi, R.; Hughes, C. (2020) *Forensic Science: History and Development*.

Forensic Chemistry: a timeline of the field

- helped to establish forensic science as a field
- applied scientific methods to crime scene analysis
- Published *Handbuch für Untersuchungsrichter*
- cross-transfer of evidence: dirt, fingerprints, hair, carpet fibers

Alphonse Bertillon **Hans Gross**

1879 **1893**

Malhi, R.; Hughes, C. (2020) *Forensic Science: History and Development*.

Forensic Chemistry: a timeline of the field

- French policeman: known as the Sherlock Holmes of France
- Locard’s Exchange Principle
- whenever two objects contact, materials are exchanged between them
- Case study of the counterfeit coins

Alphonse Bertillon — **1879**

Hans Gross — **1893**

Edmond Locard — **1885-1914**

Malhi, R.; Hughes, C. (2020) *Forensic Science: History and Development*.

Forensic Chemistry: a timeline of the field

- French physician
- produced autopsy standards from direct studies of victims' bodies
- pioneer in bloodstain pattern analysis
- Mentor to Locard

Alphonse Bertillon **Hans Gross** **Edmond Locard**

1879 **1893** **1885-1914** **1893**

Alexandre Lacassagne

Malhi, R.; Hughes, C. (2020) *Forensic Science: History and Development*.

Forensic Chemistry: a timeline of the field

- a national and international organization to uphold scientific standard
- supports research and education efforts surrounding forensic sciences
- hosts national meetings and conferences
- Journal of Forensic Sciences

AAFS
AMERICAN ACADEMY OF FORENSIC SCIENCES
EST. 1948

Alphonse Bertillon — 1879

Hans Gross — 1893

Edmond Locard — 1885-1914

Alexandre Lacassagne — 1893

establishment of the AAFS — 1948

Malhi, R.; Hughes, C. (2020) *Forensic Science: History and Development*.

Forensic Chemistry: a timeline of the field

- Professor at the University of Leicester
- developed the concept of DNA fingerprinting
- realized that variation in the genetic code could be used to identify individuals

Alphonse Bertillon **Hans Gross** **Edmond Locard**

1879 **1893** **1885-1914** **1893** **1948** **1948**

Alexandre Lacassagne **establishment of the AAFS** **Sir Alec Jeffreys**

Malhi, R.; Hughes, C. (2020) *Forensic Science: History and Development*.

Forensic Chemistry: a timeline of the field

DNA Analysis' first appearance in courtroom

- a double murder in neighboring villages in Leicestershire was the first to utilize DNA profiling
- DNA samples were collected from both crime scenes, and the blood type matched a suspect, Richard Buckland
- DNA profiling by Jeffreys acquitted Buckland, and all males in the towns were asked to provide DNA samples
- An imposter claiming to be Colin Pitchfork came to give his sample

1987

Malhi, R.; Hughes, C. (2020) *Forensic Science: History and Development*.

Forensic Chemistry: a timeline of the field

- a national and international DNA databases
- searchable databases to match crime scene DNA profiles to those in the database

DNA Analysis' first appearance in US courtroom

1987

Establishment of CODIS

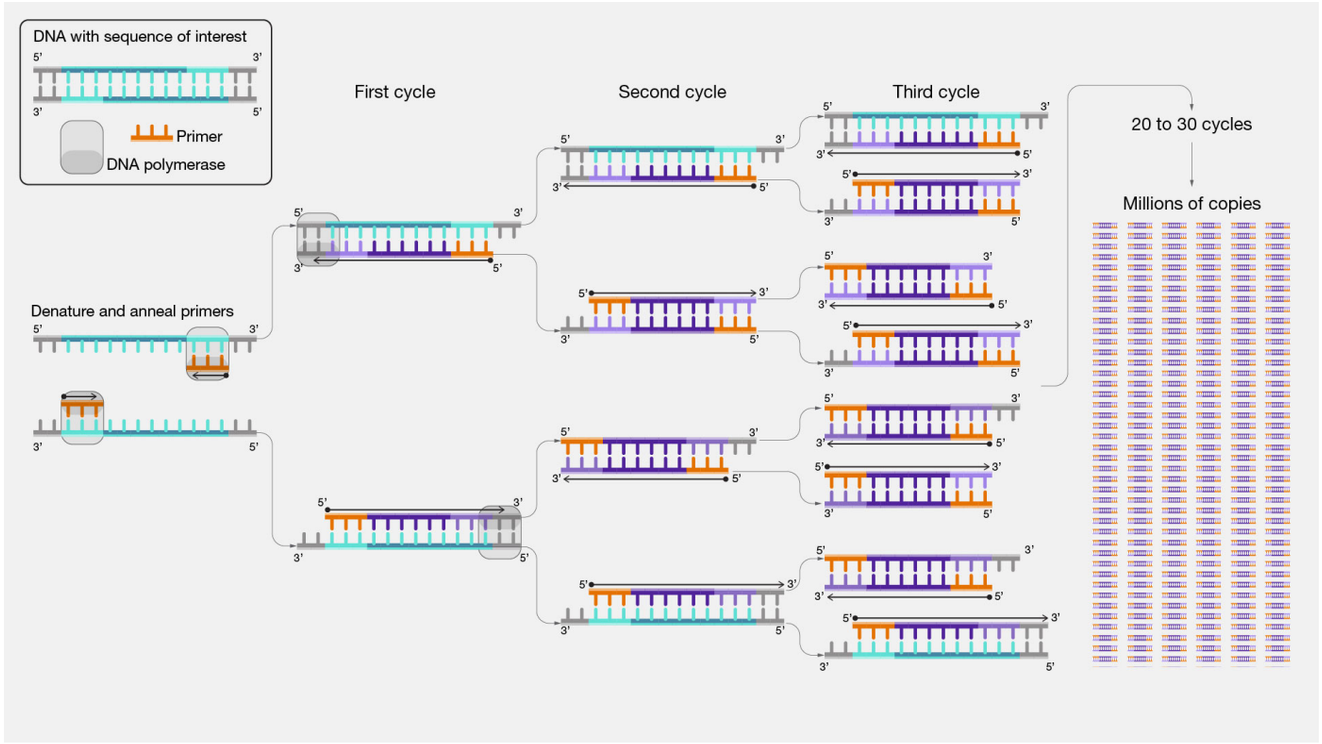
1990

ENFSI

EUROPEAN NETWORK OF FORENSIC SCIENCE INSTITUTES

Malhi, R.; Hughes, C. (2020) *Forensic Science: History and Development*.

Forensic Chemistry: a timeline of the field



1987 — **DNA Analysis' first appearance in US courtroom**

1990 — **Establishment of CODIS**

1992 — **PCR is introduced**

1994 — **DNA analysis of short tandem repeats introduced**

1996 — **mtDNA is first admitted to US courtroom**

Malhi, R.; Hughes, C. (2020) *Forensic Science: History and Development*.

Outline for the talk

- **Analytical Chemistry**
- **DNA in Forensic Science**
- **Fingerprinting**
- **Forensic Specialties**

Outline for the talk

- **Analytical Chemistry**
- **DNA in Forensic Science**
- **Fingerprinting**
- **Forensic Specialties**

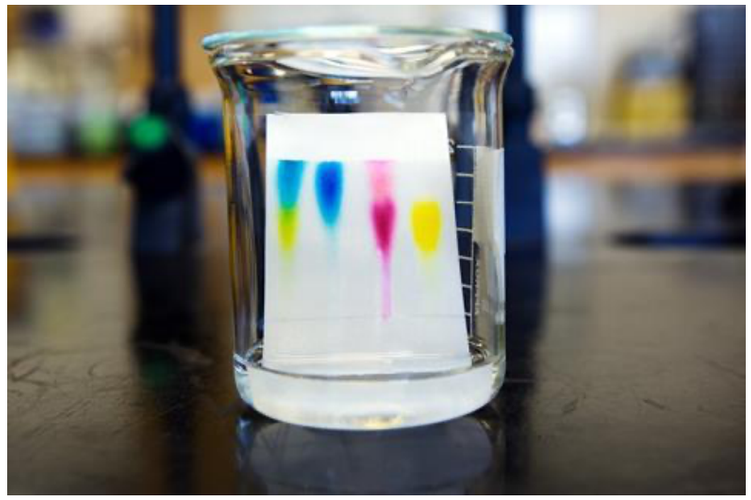
Analytical Chemistry in forensic science

What types of analytical techniques are used in forensic chemistry labs?

Analytical Chemistry

GC-MS

TLC



LC-MS

IR/FT-IR

Malhi, R.; Hughes, C. (2020) *CSI: Securing, Recording, and Analyzing Evidence*.

Analytical Chemistry

GC-MS

detection of volatile materials at a crime scene

TLC

confirmation of suspected drugs

LC-MS

identification of unknown substances

IR/FT-IR

fiber and material analysis

Malhi, R.; Hughes, C. (2020) *CSI: Securing, Recording, and Analyzing Evidence*.

Analytical Chemistry in forensic science

What types of analytical techniques are used in forensic chemistry labs?

Analytical techniques are used for the analysis, identification, and confirmation of physical evidence

Fragile/Transient Evidence

needs to be carefully maintained or reproduced in a more stable state

footprints, fingerprints, blood, gunshot residue

Solid/Tangible Evidence

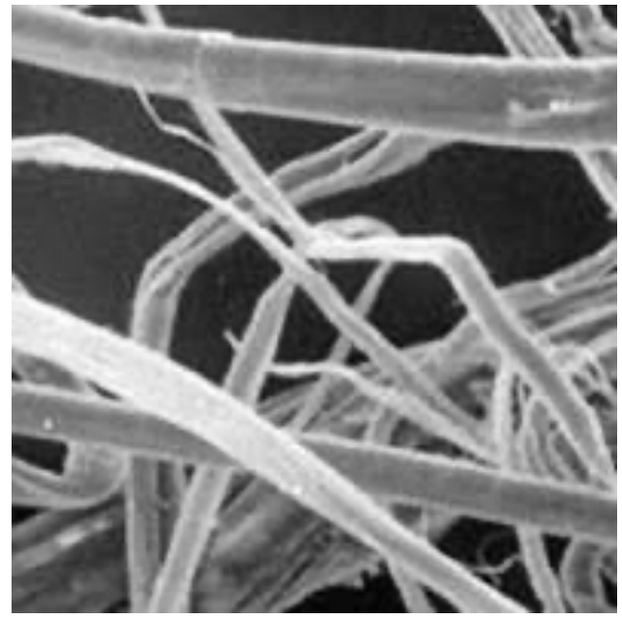
evidence that is stable overt time

firearms, clothing, documents, electronics

Malhi, R.; Hughes, C. (2020) *CSI: Securing, Recording, and Analyzing Evidence*.

Physical Evidence

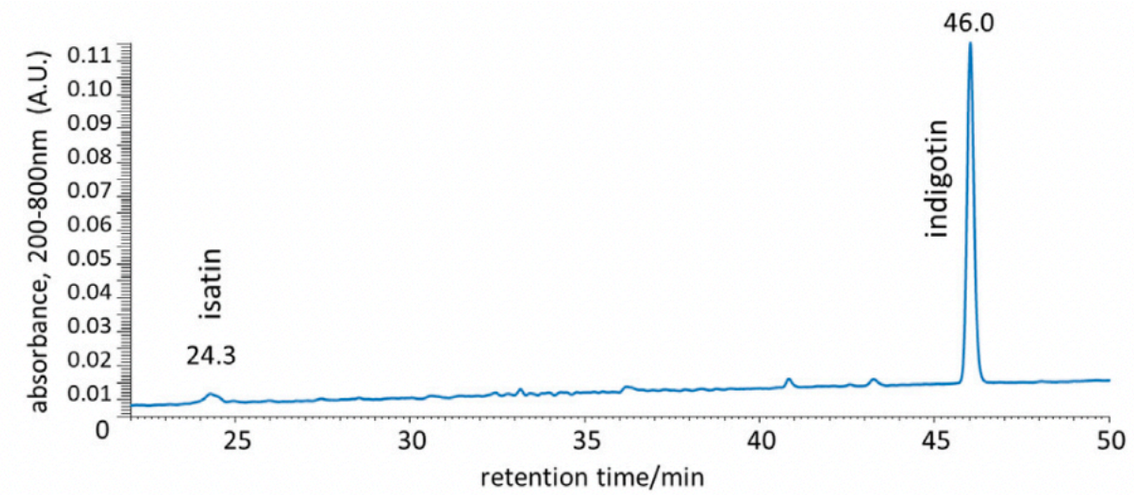
…and how a forensic chemist may analyze this evidence



Take a simple carpet fiber, for example…

Smith, G.; Esson, J.; Chen, V.; Hanson, R. *Forensic Science International: Synergy 3.* **2021**, 100130.

Physical Evidence

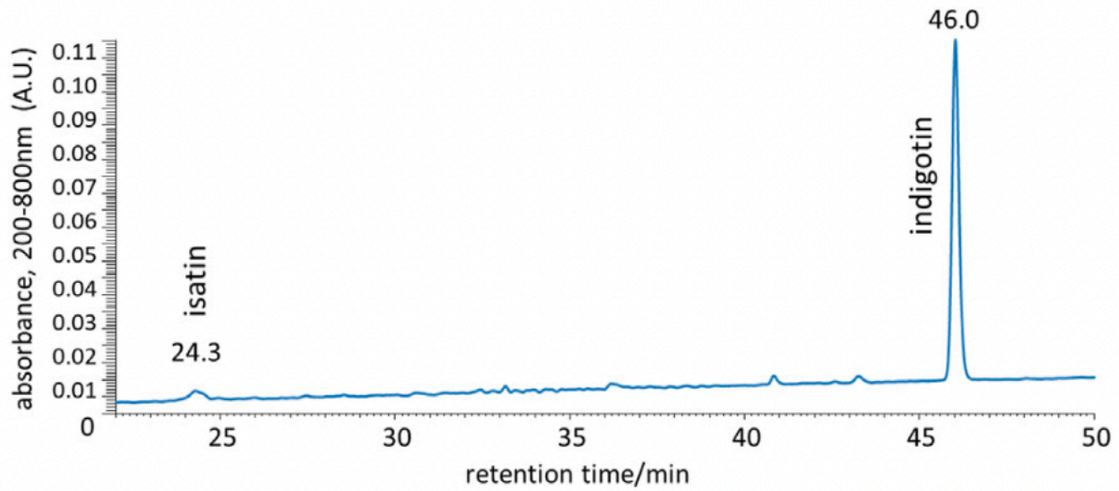


LC-MS analysis
can show with certainty the identity of compounds present in the carpet sample

dye composition *mass signal* *retention time*

Smith, G.; Esson, J.; Chen, V.; Hanson, R. *Forensic Science International: Synergy 3.* **2021**, 100130.

Physical Evidence

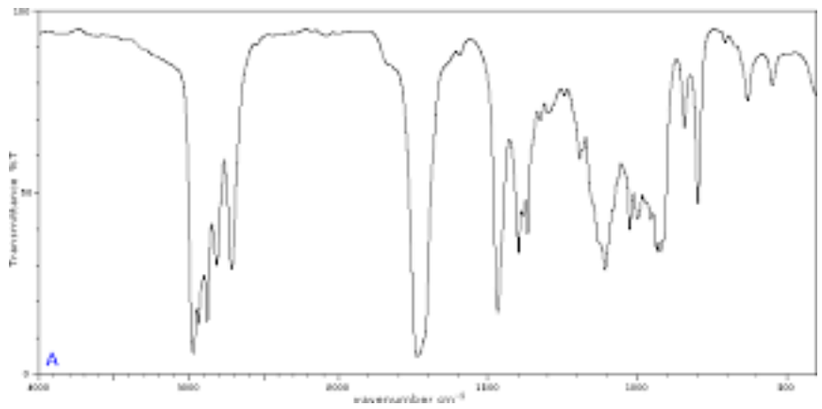


LC-MS analysis
can show with certainty the identity of compounds present in the carpet sample

dye composition

mass signal

retention time



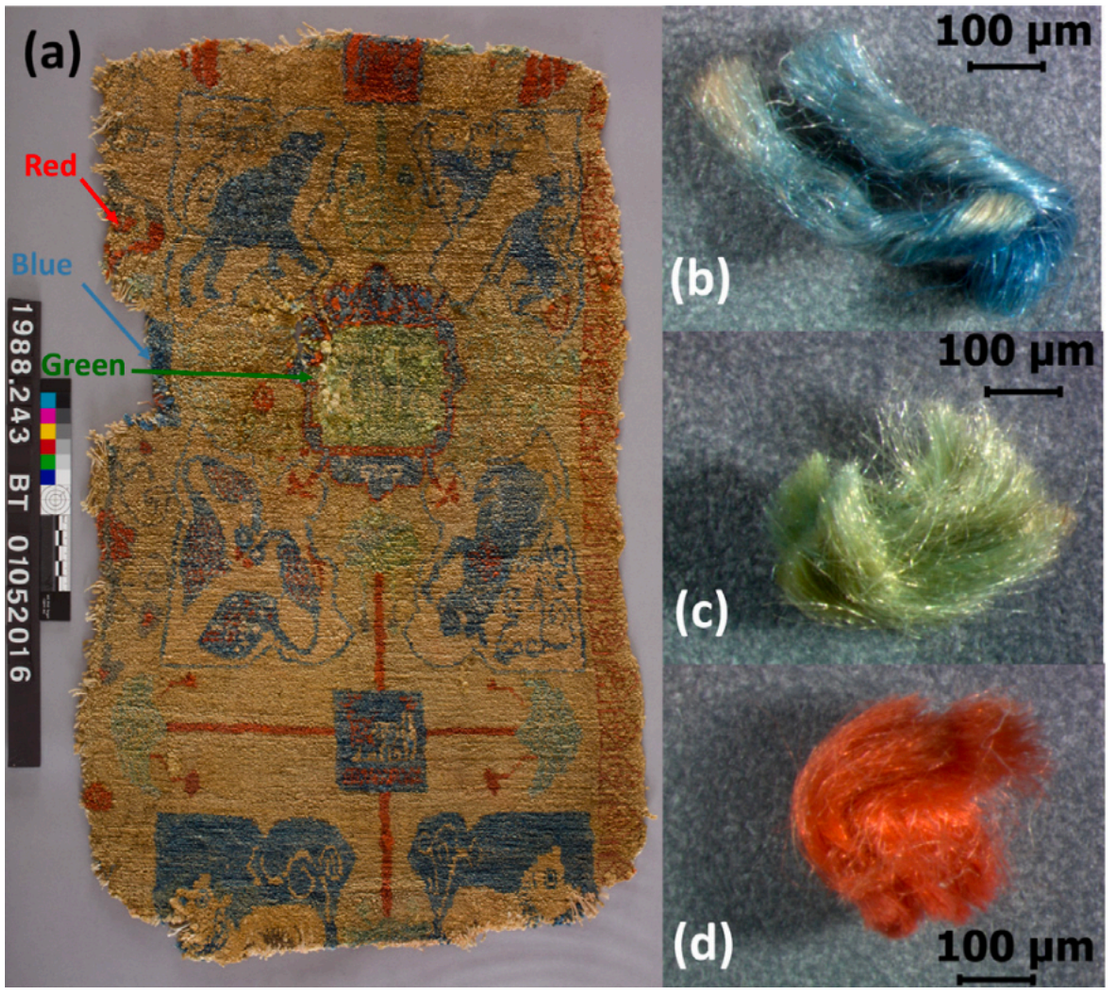
IR spectrometry
different fibers give different bands in IR

Smith, G.; Esson, J.; Chen, V.; Hanson, R. *Forensic Science International: Synergy 3.* **2021**, 100130.

Physical Evidence: Case Study

Carpet Fiber Analysis Case Study

dye analysis is a common technique in forensic investigations:
hair, textiles, fibers found at crime scene

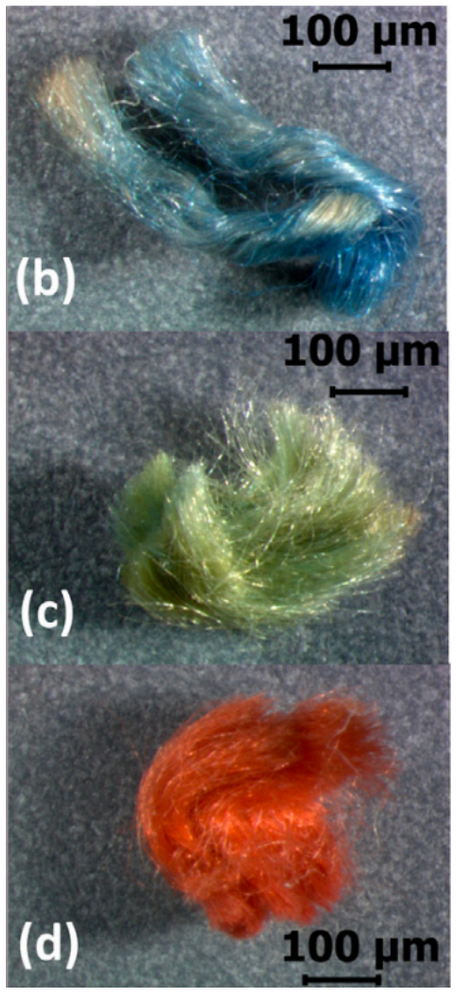


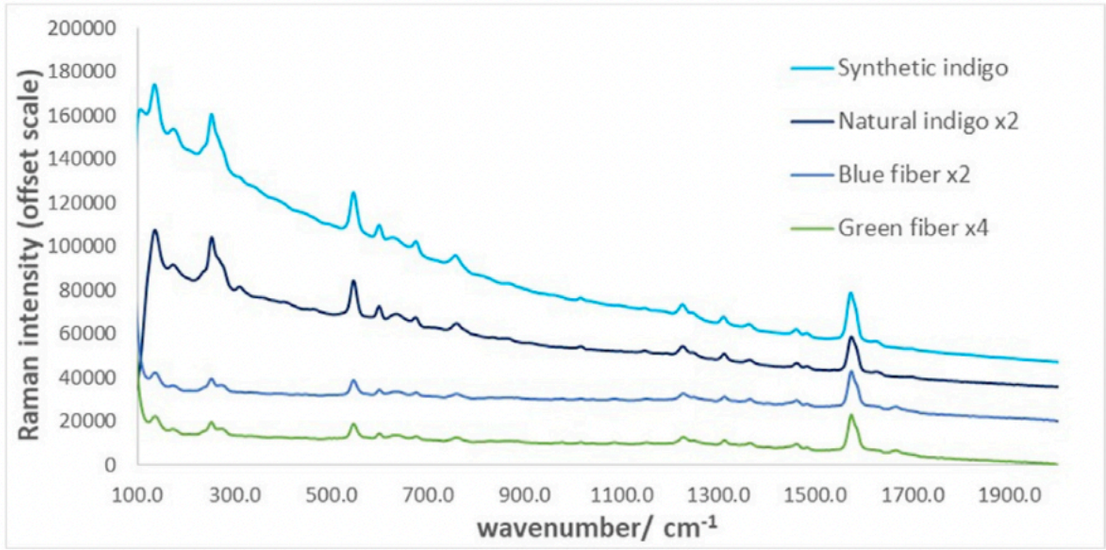
This carpet was proposed to be a 15th century Persian silk rug

How would a forensic chemist determine the age of the rug fibers?

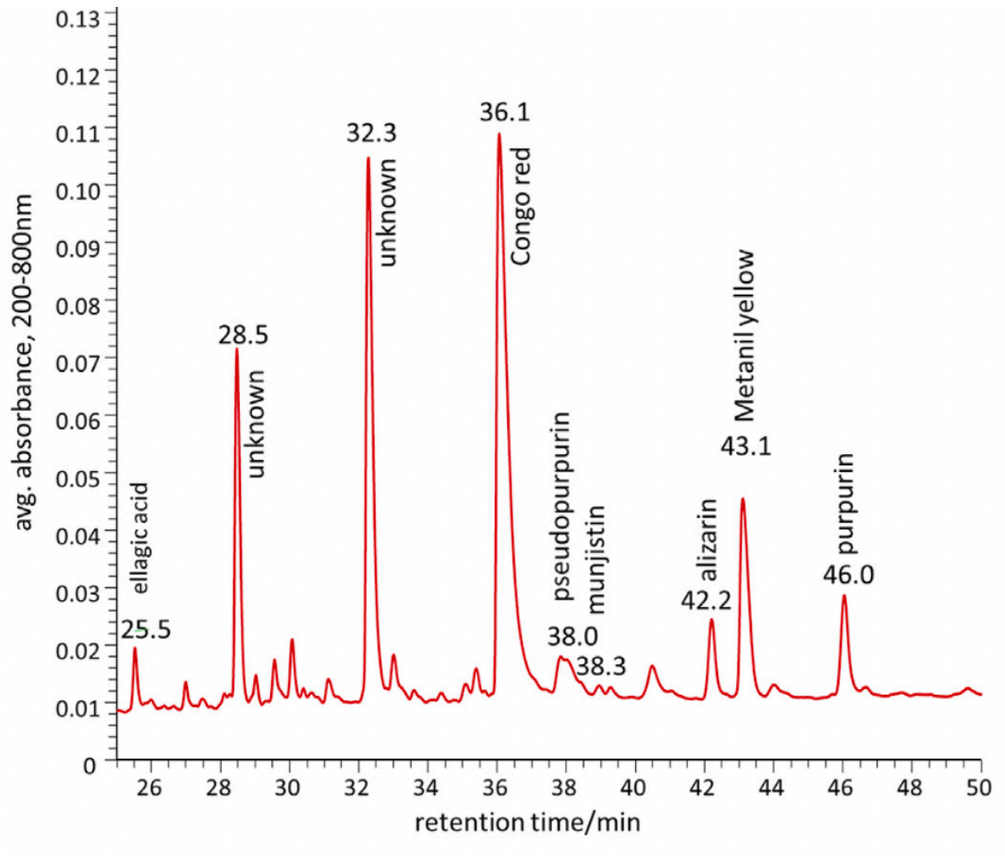
Smith, G.; Esson, J.; Chen, V.; Hanson, R. *Forensic Science International: Synergy 3.* **2021**, 100130.

Physical Evidence: Case Study

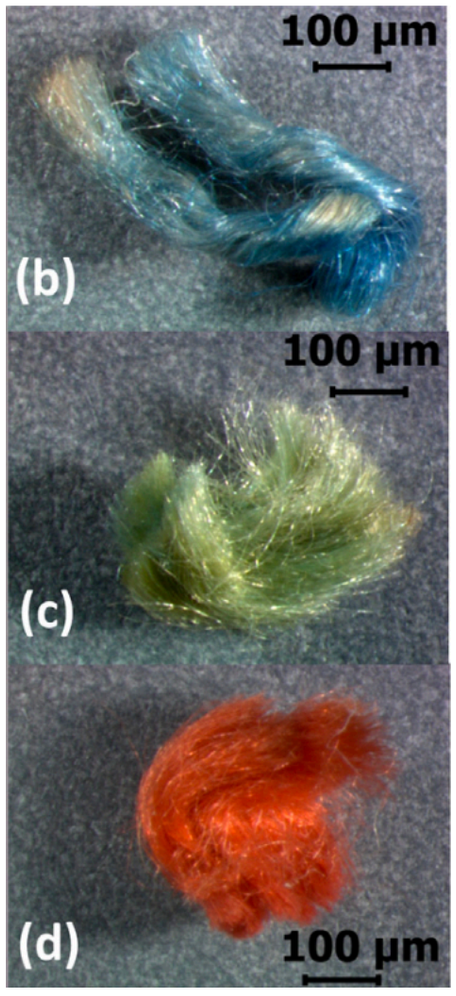




LC-MS analysis
can show with certainty the identity of compounds present in the carpet sample

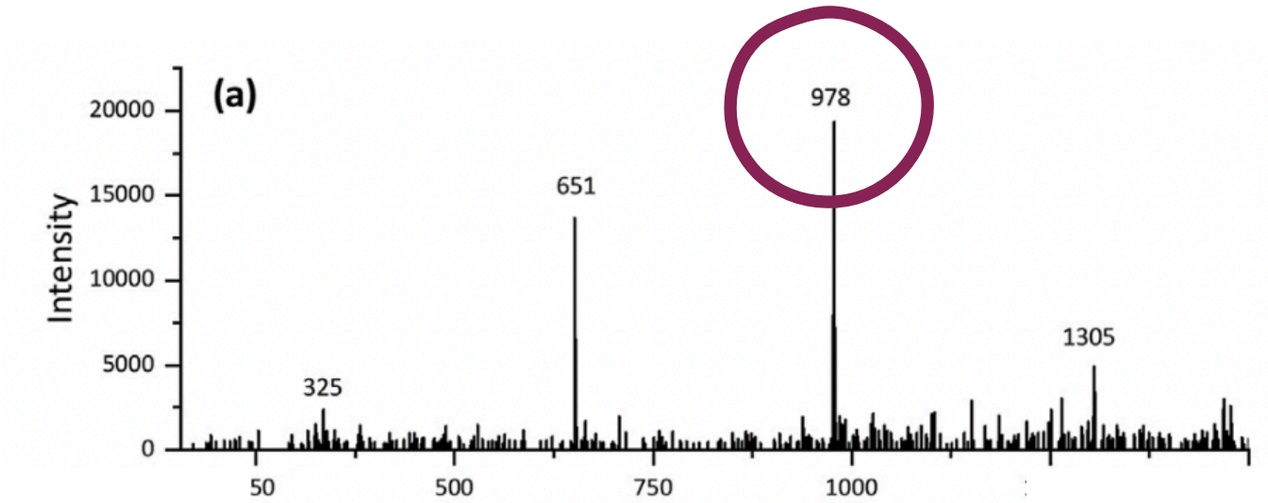


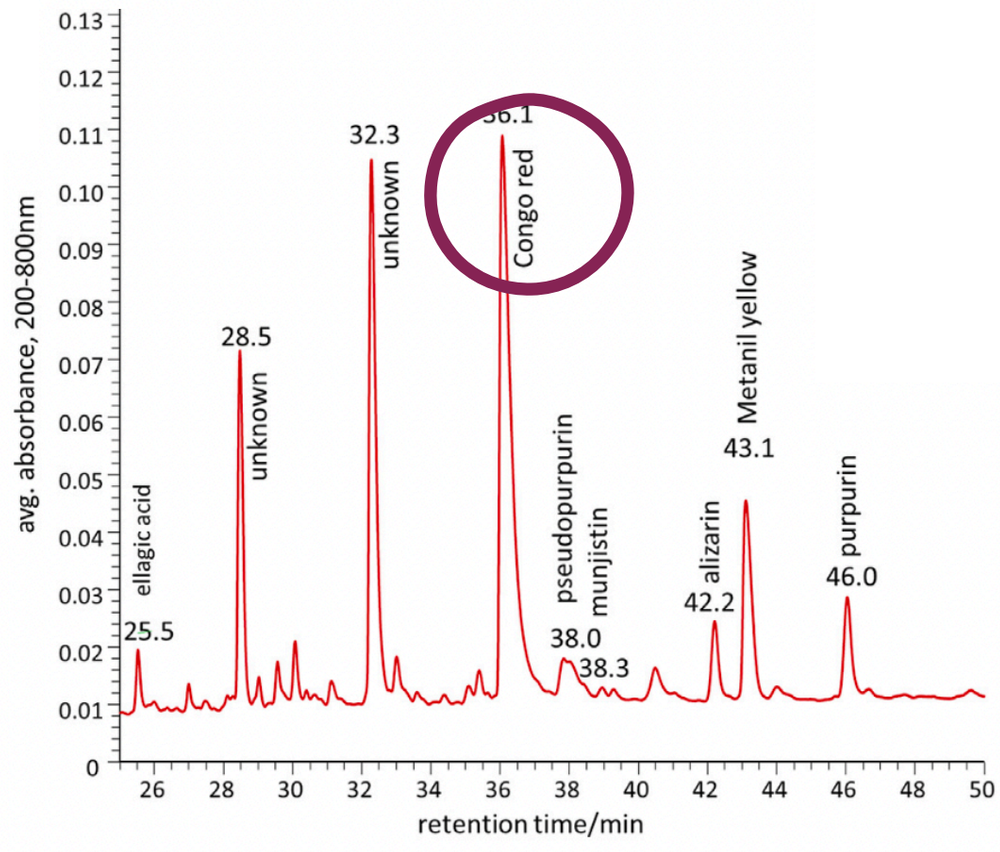
Physical Evidence: Case Study



LC-MS analysis
can show with certainty the identity of compounds present in the carpet sample

LC-MS analysis
identified the red carpet fiber as containing Congo Red, a dye created in 1884

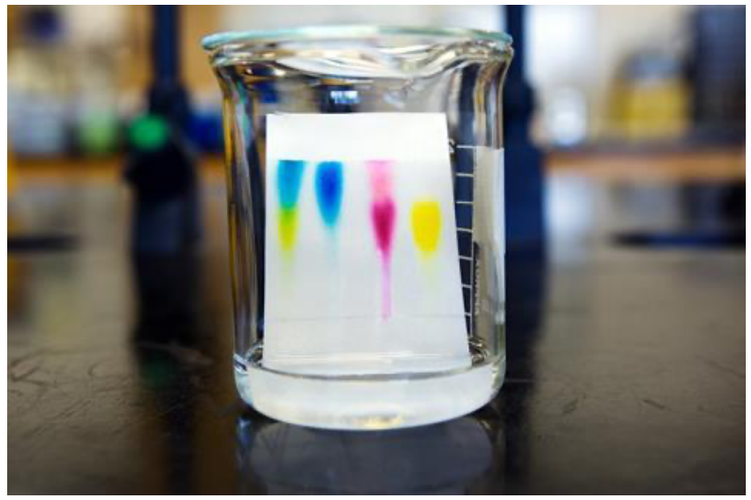




Analytical Chemistry

GC-MS

TLC



LC-MS

IR/FT-IR

Malhi, R.; Hughes, C. (2020) *CSI: Securing, Recording, and Analyzing Evidence*.

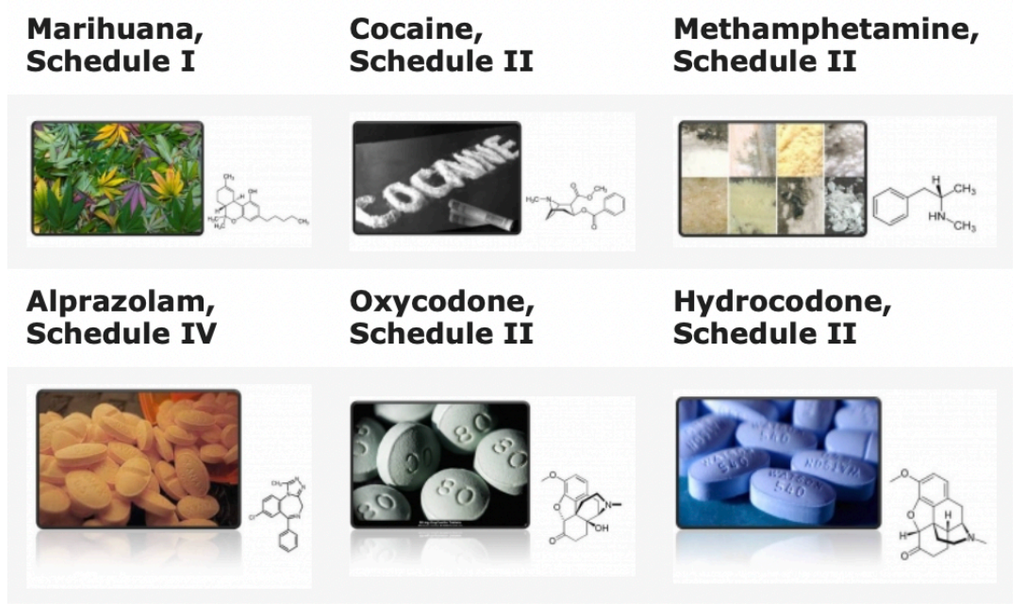
Comparative analysis: how the crime lab comes into play

Oklahoma State Crime Lab

Malhi, R.; Hughes, C. (2020) *CSI: Securing, Recording, and Analyzing Evidence*.

Reasons for Forensic Toxicological Analysis

- *driving under the influence*
- *drug-related homicides*
- *drug-related child endangerment*
- *drug-related sexual assaults*
- *poisons*
- *alcohol content*

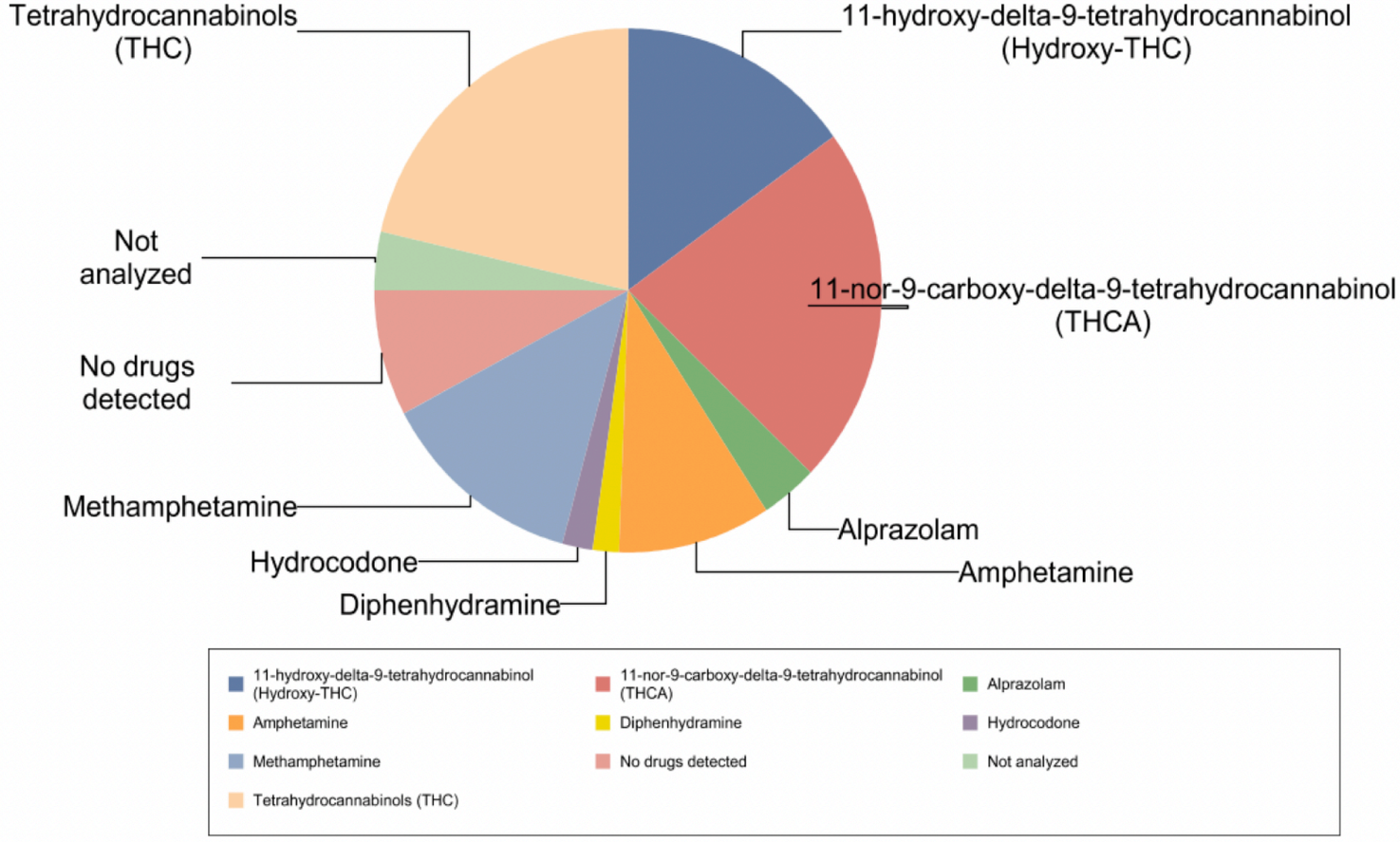


Malhi, R.; Hughes, C. (2020) *CSI: Securing, Recording, and Analyzing Evidence*.

Analytical Chemistry: Opiate Analysis

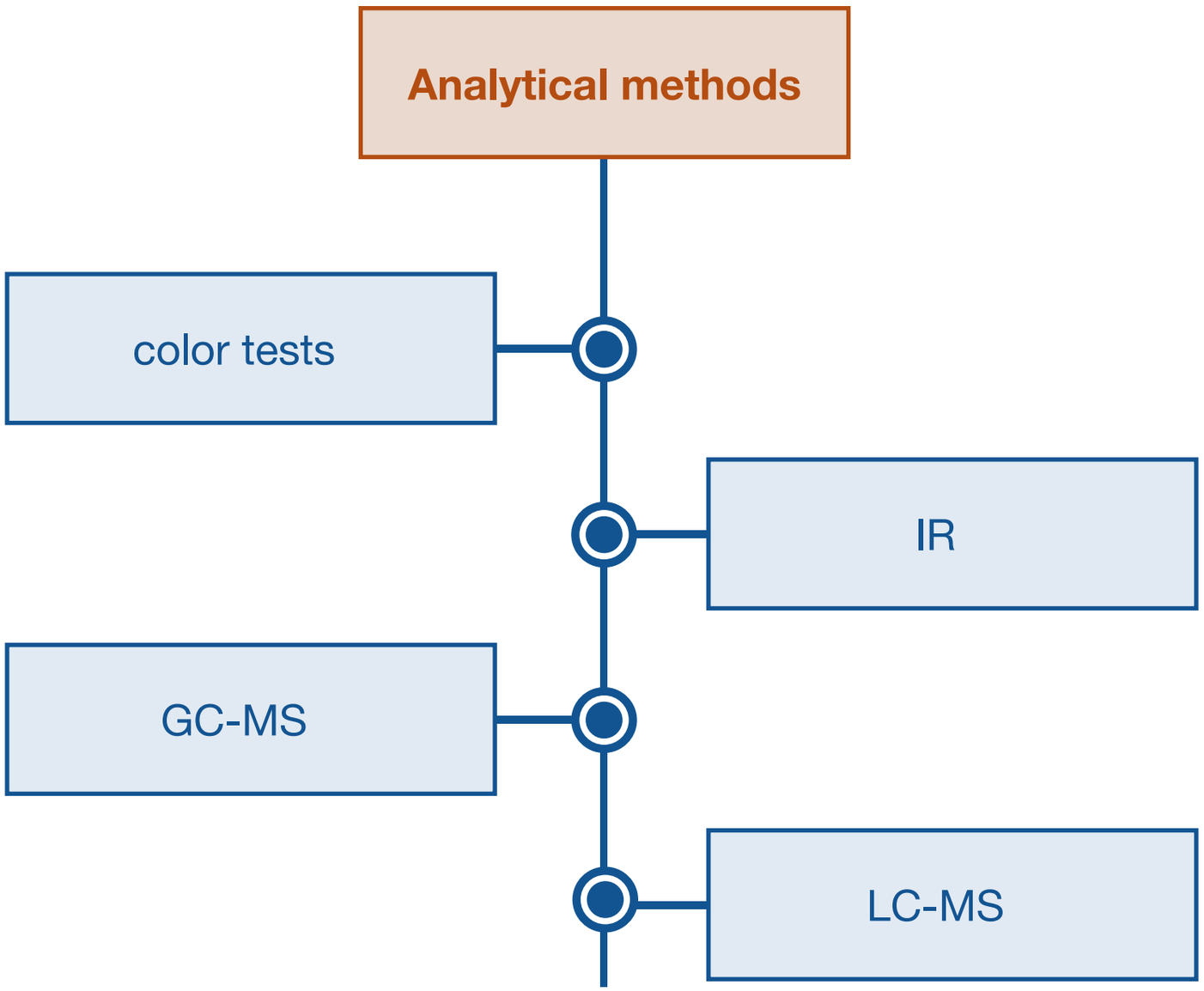
Top Drugs Ecountered in 2020

Oklahoma State Bureau of Investigation



Malhi, R.; Hughes, C. (2020) *CSI: Securing, Recording, and Analyzing Evidence*.

Analytical Chemistry: Opiate Analysis

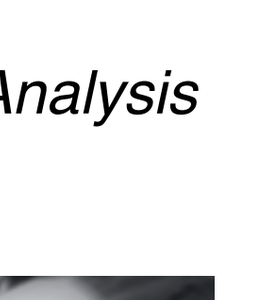


Malhi, R.; Hughes, C. (2020) *CSI: Securing, Recording, and Analyzing Evidence*.

Analytical Chemistry: Opiate Analysis

Analytical methods

- color tests



ketamine

CoSCN is a common presumptive color test for ketamine, cocaine, and others

Morris, J. *J. Forensic Sci.* **2007**, *52*, 84.

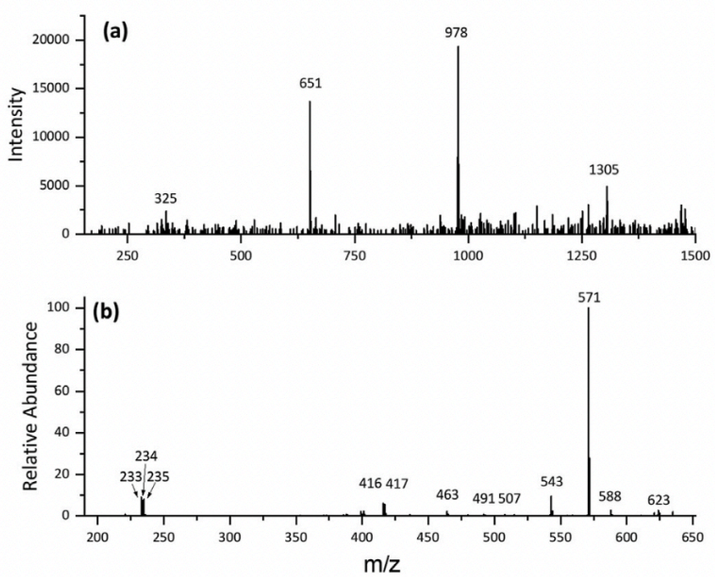
Analytical Chemistry: Opiate Analysis

Analytical methods

Positive
Creamy White
#901
MAYER'S REAGENT
Negative
No response Clear
#902
MARQUIS REAGENT
Positive
Purple
Orange
Red
Brown
MDMA BLACK
Opiates (Heroin confirm in Mecke's #924)
Immediate Green
Amphetamines...
will sequence orange-red-brown
(Ice, Methamphetamine)
923 Meth and MDMA
Immediate Dcca Blue
Negative
No response Clear
#904
COCAINE HCL, FREE-BASE, "CRACK"
After Breaking 1st Ampoule
Blue
After Breaking 2nd Ampoule
Pink
After Breaking 3rd Ampoule
Pink Over Blue
#905
DILLE KOPPANYI REAGENT
Positive
Light Purple
Barbiturates
Negative
No response
#907
EHRLICH'S REAGENT
Positive
Purple
LSD
Negative
No response
NOTE: ALL SUSPECT MATERIALS PRODUCING NEGATIVE RESPONSES SHOULD BE SENT TO THE LAB FOR FURTHER TESTING.
For All Plant Materials and Oils
#908 DUQUENOIS LEVINE REAGENT
Slate Grey Over Purple
#909 KN REAGENT
Marihuana
Reddish Brown
Hashish, Hash Oil, THC
Dk Reddish Brown

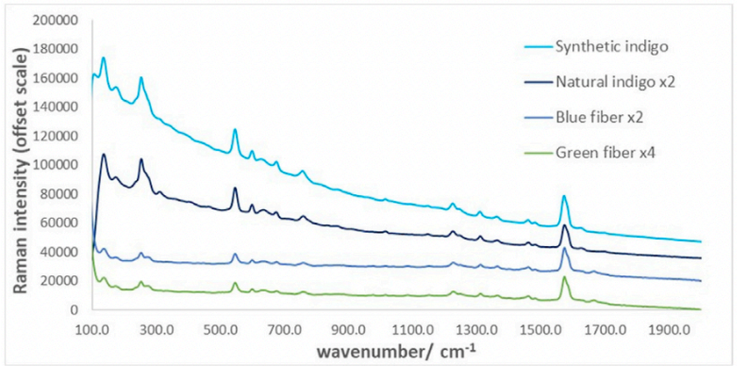
Lancashire, R. *Chemistry and Crime*, **2014**.

Analytical Chemistry: Opiate Analysis



Analytical methods

- color tests
- IR
- GC-MS
- LC-MS



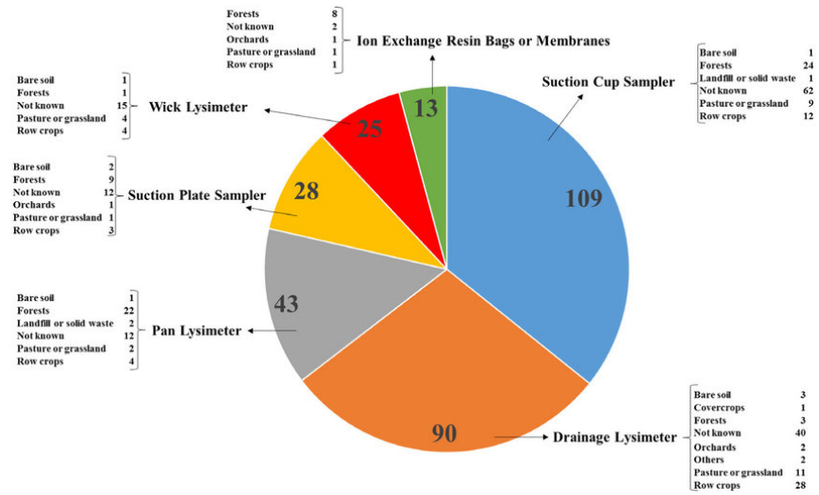
Malhi, R.; Hughes, C. (2020) *CSI: Securing, Recording, and Analyzing Evidence*.

Comparative analysis: how the crime lab comes into play

Case Study:
pollen, potassium, phosphorus content on a soil sample at a grave

A sample of soil is taken from a grave as evidence

Soil sample from suspect



known soil composition

Let’s show the math, all very quantifiable, assuming you have the data!!

Malhi, R.; Hughes, C. (2020) *CSI: Securing, Recording, and Analyzing Evidence*.

Comparative analysis: how the crime lab comes into play

Case Study:
pollen, potassium, phosphorus content on a soil sample at a grave

A sample of soil is taken from a grave as evidence

- Pollen: in 25% of soil
- Phosphorus: in 50% of soil
- Potassium: in 10% of soil

What is the probability of finding **all 3 in combination** in a sample?

Note: all events must be independent!

P(A and B)=P(A)*P(B)=random match probability (RMP)

Malhi, R.; Hughes, C. (2020) *CSI: Securing, Recording, and Analyzing Evidence*.

Comparative analysis: how the crime lab comes into play

Case Study:
pollen, potassium, phosphorus content on a soil sample at a grave

A sample of soil is taken from a grave as evidence

- Pollen: in 25% of soil
- Phosphorus: in 50% of soil
- Potassium: in 10% of soil

What is the probability of finding **all 3 in combination** in a sample?

P(pollen) = 0.25

P(P) = 0.50

P(K) = 0.10

Probability(P) = 0.25(0.50)(0.10) = 0.0125 = 1.25%

Malhi, R.; Hughes, C. (2020) *CSI: Securing, Recording, and Analyzing Evidence*.

Comparative analysis: how the crime lab comes into play

Case Study:
pollen, potassium, phosphorus content on a soil sample at a grave

A sample of soil is taken from a grave as evidence

Case Study Part 2:

- Remains are found that have a hip replacement implant (167482828) matching a batch of 100 implants with the same serial number

- It is known that there are 89,000 hip replacement parts in circulation in the US

Probability of serial number(P) = 100/89,000 = 0.001 = 0.1%

Malhi, R.; Hughes, C. (2020) *CSI: Securing, Recording, and Analyzing Evidence*.

Comparative analysis: how the crime lab comes into play

Case Study:
pollen, potassium, phosphorus content on a soil sample at a grave

A sample of soil is taken from a grave as evidence

- Furthermore, soil was found underneath the individual's fingers. It was determined to be bentonite, which ~5% of the US population lives near
- Database returned a possible match: T.W. Dwight, who lived in and area with bentonite in the soil and had a hip replacement matching the serial number

Random Match Probability (RMP) = 0.001(0.05) = 0.00005 = 0.005%

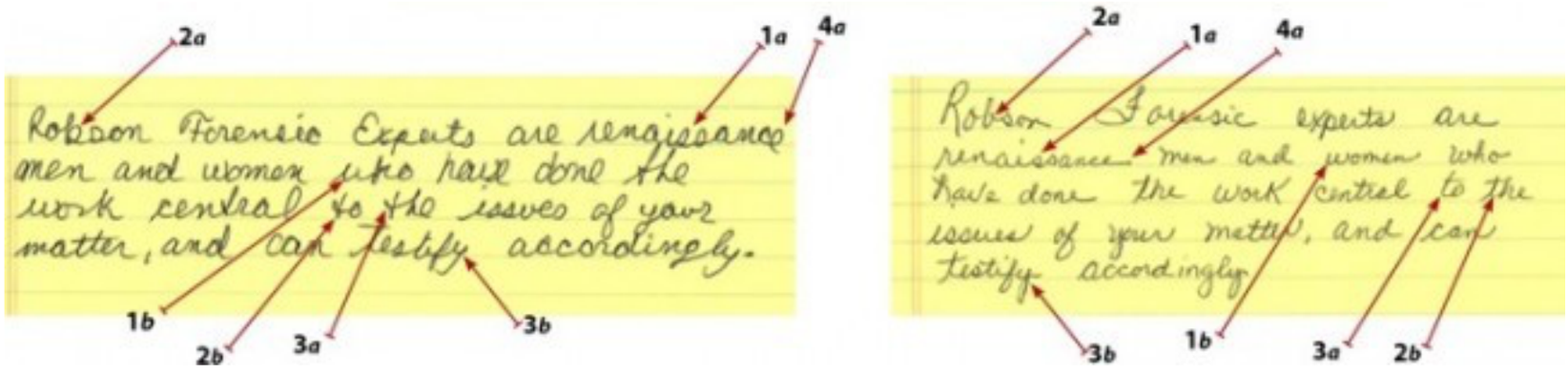
Probability of Identity (P) = 100%-0.005% = 99.995%

Malhi, R.; Hughes, C. (2020) *CSI: Securing, Recording, and Analyzing Evidence*.

Physical Evidence

what if you don't have specific data like % phosphorus in soil?

- handwriting
- fingerprints
- tattoos



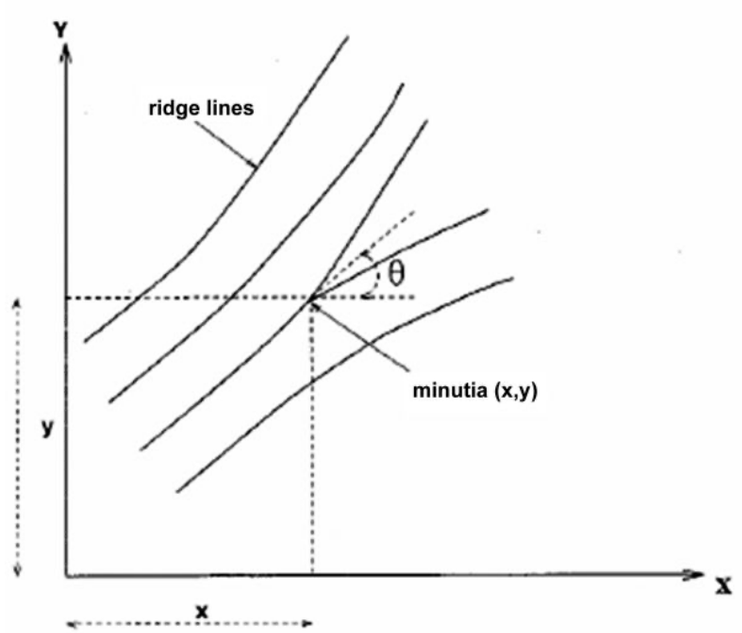
How many characteristics can you quantify before you can conclude it's a match?

Malhi, R.; Hughes, C. (2020) *CSI: Securing, Recording, and Analyzing Evidence*.

Physical Evidence

what if you don't have specific data like % phosphorus in soil?

- handwriting
- fingerprints
- tattoos



vector field

more on fingerprints later

Yang, J. Minutiae-based Fingerprint Extraction and Recognition in *Biometrics*, 2011.

Outline for the talk

- **Analytical Chemistry**
- **DNA in Forensic Science**
- **Fingerprinting**
- **Forensic Specialties**

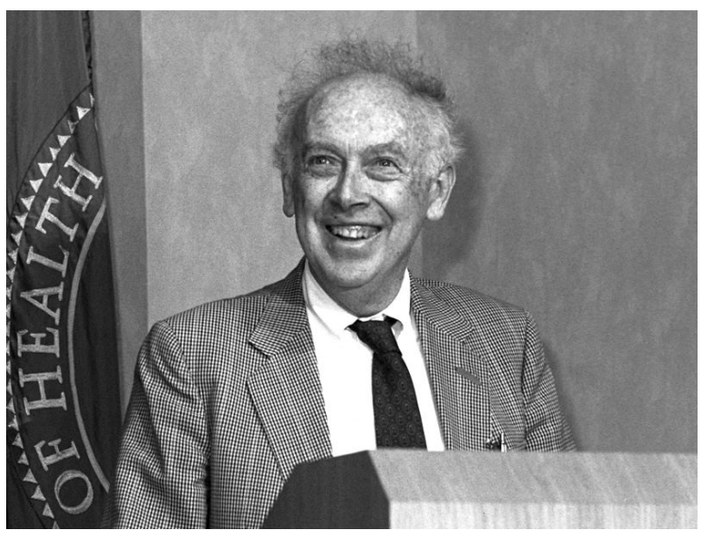
Outline for the talk

- Analytical Chemistry
- **DNA in Forensic Science**
- Fingerprinting
- Forensic Specialties

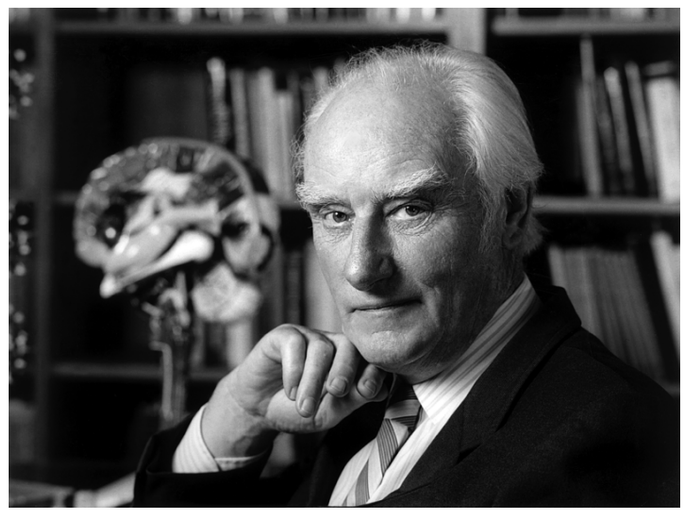
DNA in Forensic Science

Rosalind Franklin

Francis Crick

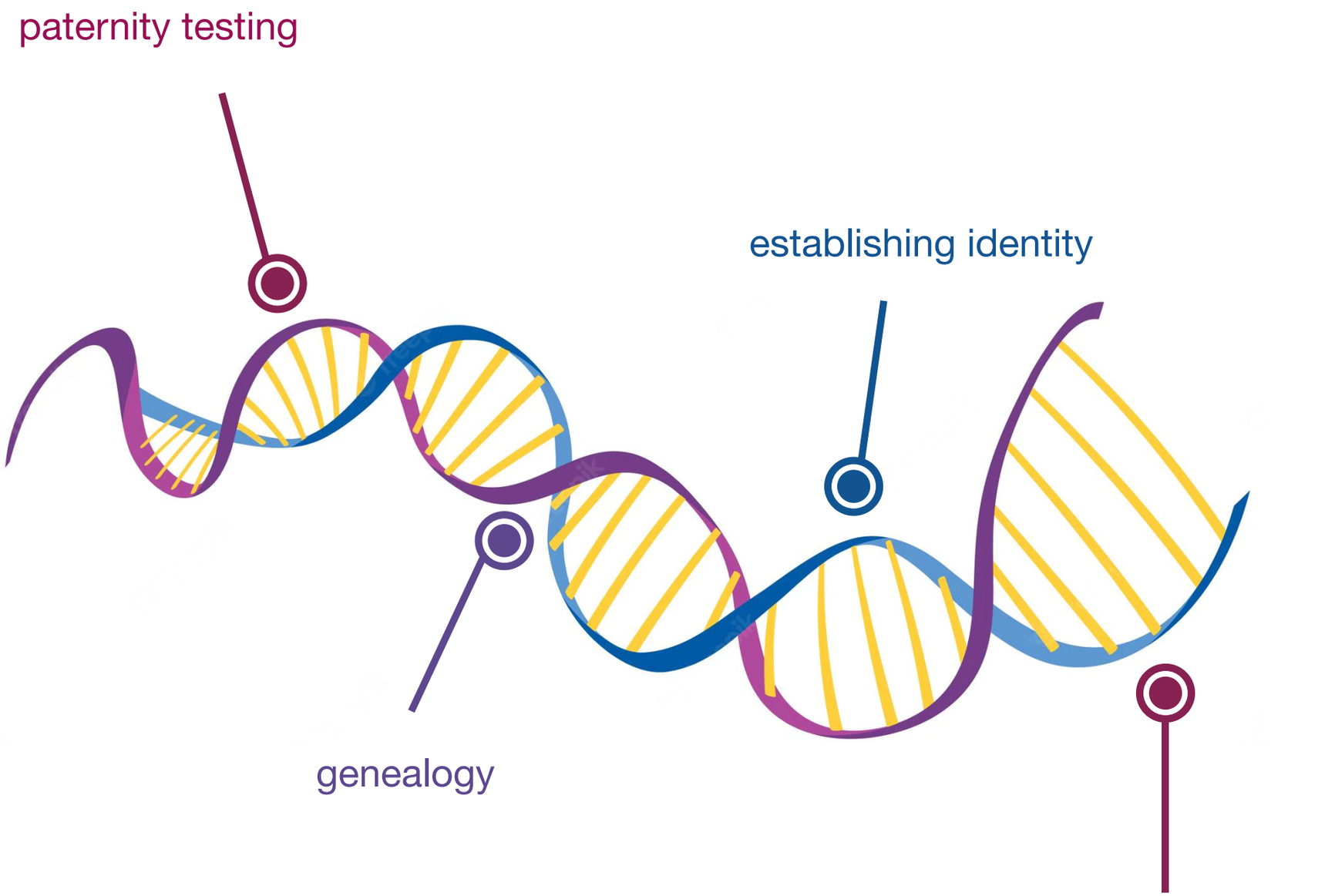


James Watson



Malhi, R.; Hughes, C. (2020) *Heredity and Environment-DNA and Phenotypic Variation*.

DNA in Forensic Science



Malhi, R.; Hughes, C. (2020) *Heredity and Environment-DNA and Phenotypic Variation*.

Population Genetics

The study of the total pattern of genetic variation of a biological population

Godfrey Harold Hardy

Hardy-Weinberg Equilibrium

Freq. of **AA**: p^2

Freq. of **Aa**: $2pq$

Freq. of **aa**: q^2

$$p^2 + 2pq + q^2 = 1$$

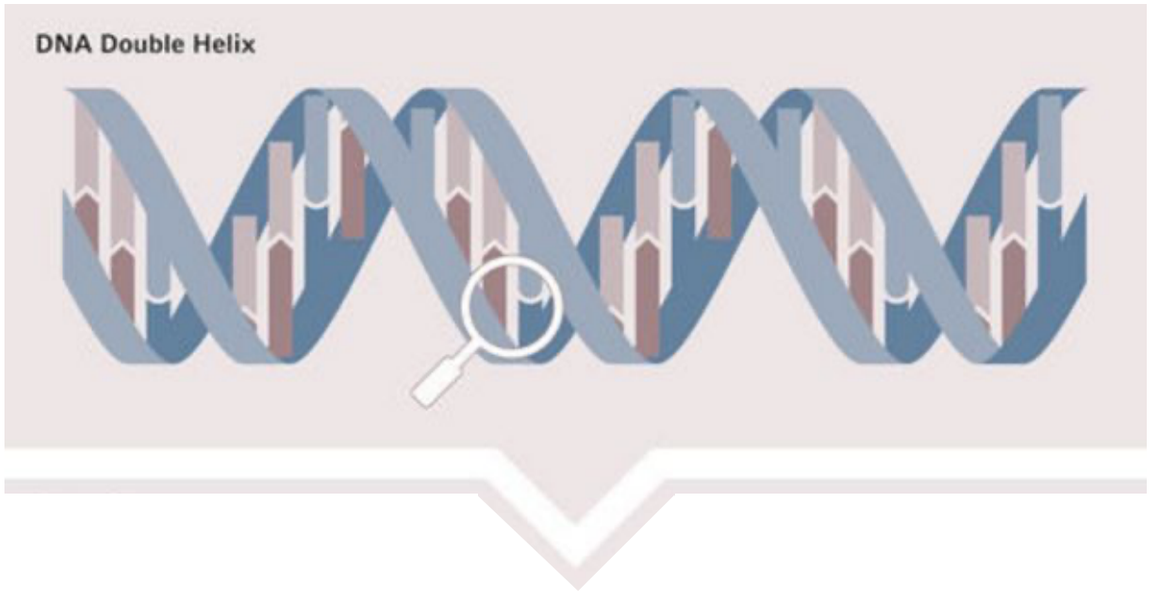
Wilhelm Weinberg

allele frequency: relative proportion of alleles within a population

$$\text{genotype frequency} = \frac{\text{individuals with each genotype}}{\text{individuals in population}}$$

Malhi, R.; Hughes, C. (2020) *Heredity and Environment-DNA and Phenotypic Variation*.

DNA Markers



Two main types of DNA markers used in forensic science

short tandem repeats (STRs)

single nucleotide polymorphism (SNP)

short repetitions of a particular set of nucleotides that is found at a particular location (locus) in the DNA.

STR variation: 2-6 base pairs

"AT" = 2 nucleotides

"CGG" = 3 nucleotides

"ATAG" = 4 nucleotides

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

DNA Markers

Two main types of DNA markers used in forensic science

short tandem repeats (STRs)

single nucleotide polymorphism (SNP)

short repetitions of a particular set of nucleotides that is found at a particular location (locus) in the DNA.

STR variation: 2-6 base pairs

"AT" = 2 nucleotides

"CGG" = 3 nucleotides

"ATAG" = 4 nucleotides

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

DNA Markers

Two main types of DNA markers used in forensic science

short tandem repeats (STRs)

single nucleotide polymorphism (SNP)

3 nucleotides, repeated 5 times

Known as Allele 5

STR variation: 2-6 base pairs

"AT" = 2 nucleotides

"CGG" = 3 nucleotides

"ATAG" = 4 nucleotides

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

DNA Markers

Two main types of DNA markers used in forensic science

short tandem repeats (STRs)

single nucleotide polymorphism (SNP)

3 nucleotides, repeated 5 times

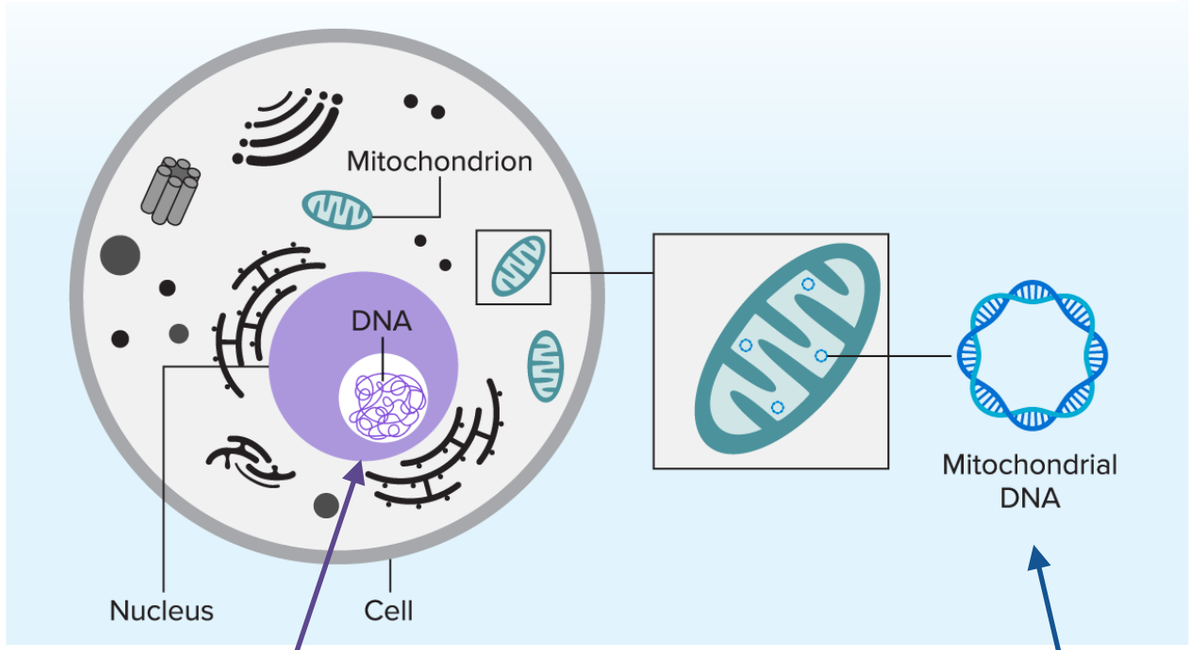
Known as Allele 5

How are STRs used in forensic genetics?

- there is also lots of variation among individuals: great for identification purposes
- compare STR alleles in DNA evidence sample to suspect sample.

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

Types of DNA



nuclear DNA: 3 billion base pairs

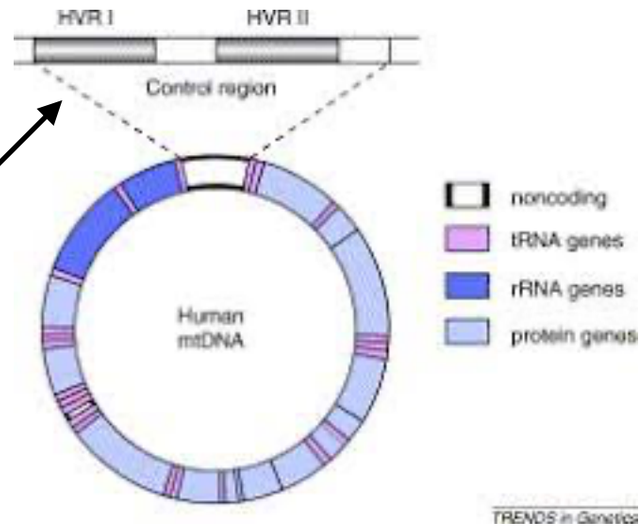
mitochondrial DNA: 16,500 base pairs

Mitochondrial DNA (MtDNA)

maternally inherited

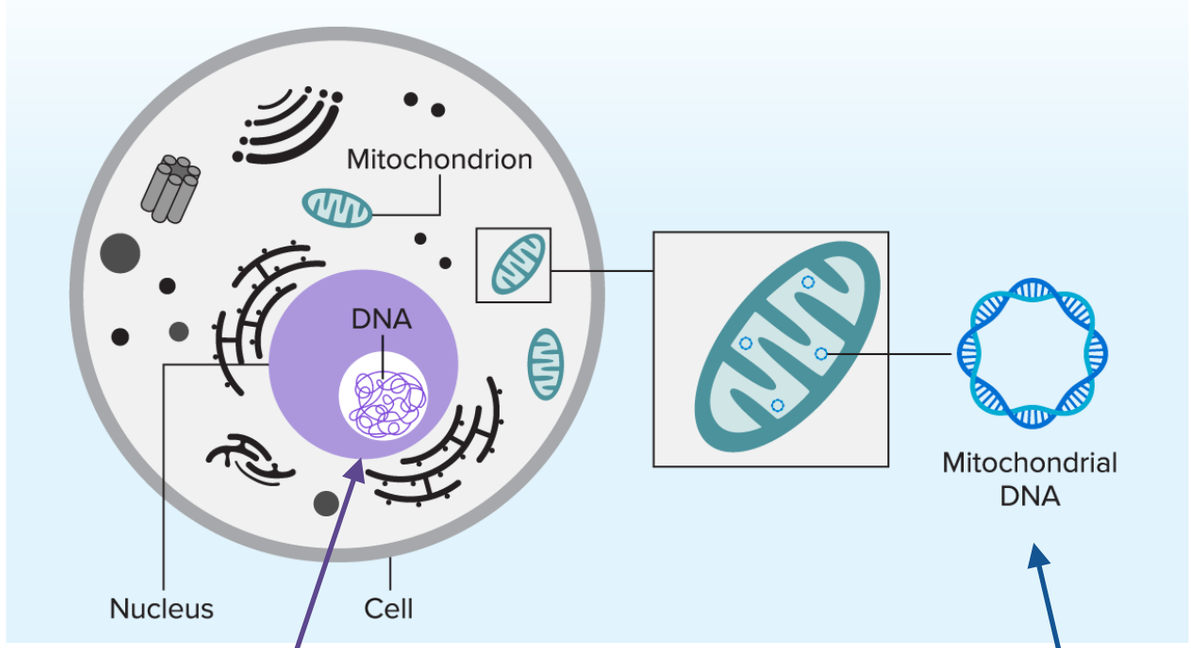
can inform about one's direct maternal line of ancestors.

control region: hypervariable!



Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

Types of DNA



nuclear DNA: 3 billion base pairs

mitochondrial DNA: 16,500 base pairs

Why is mtDNA often used in missing person's cases involving skeletal remains?

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

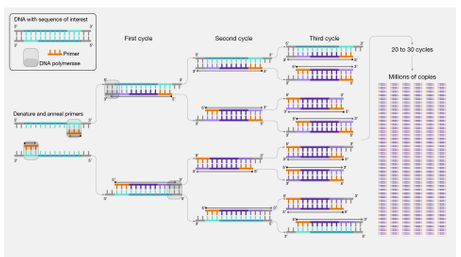
DNA in Forensic Science

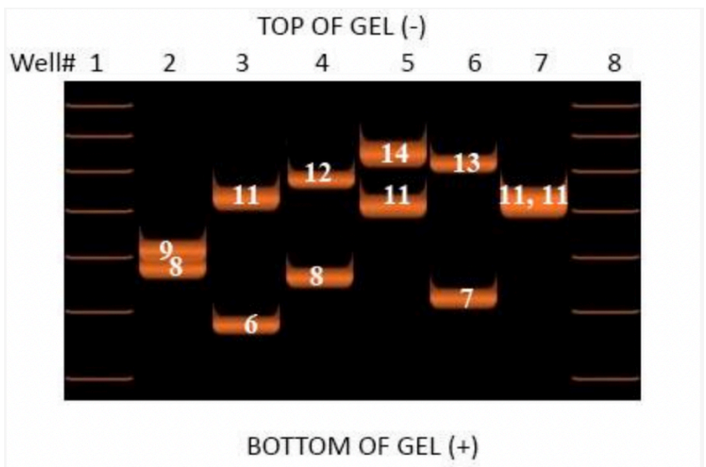
Workflow for analyzing DNA

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

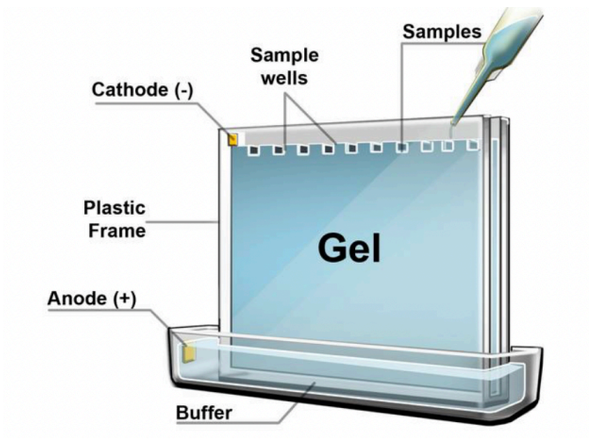
DNA in Forensic Science

Workflow for analyzing DNA





collect sample → PCR → gel → readout

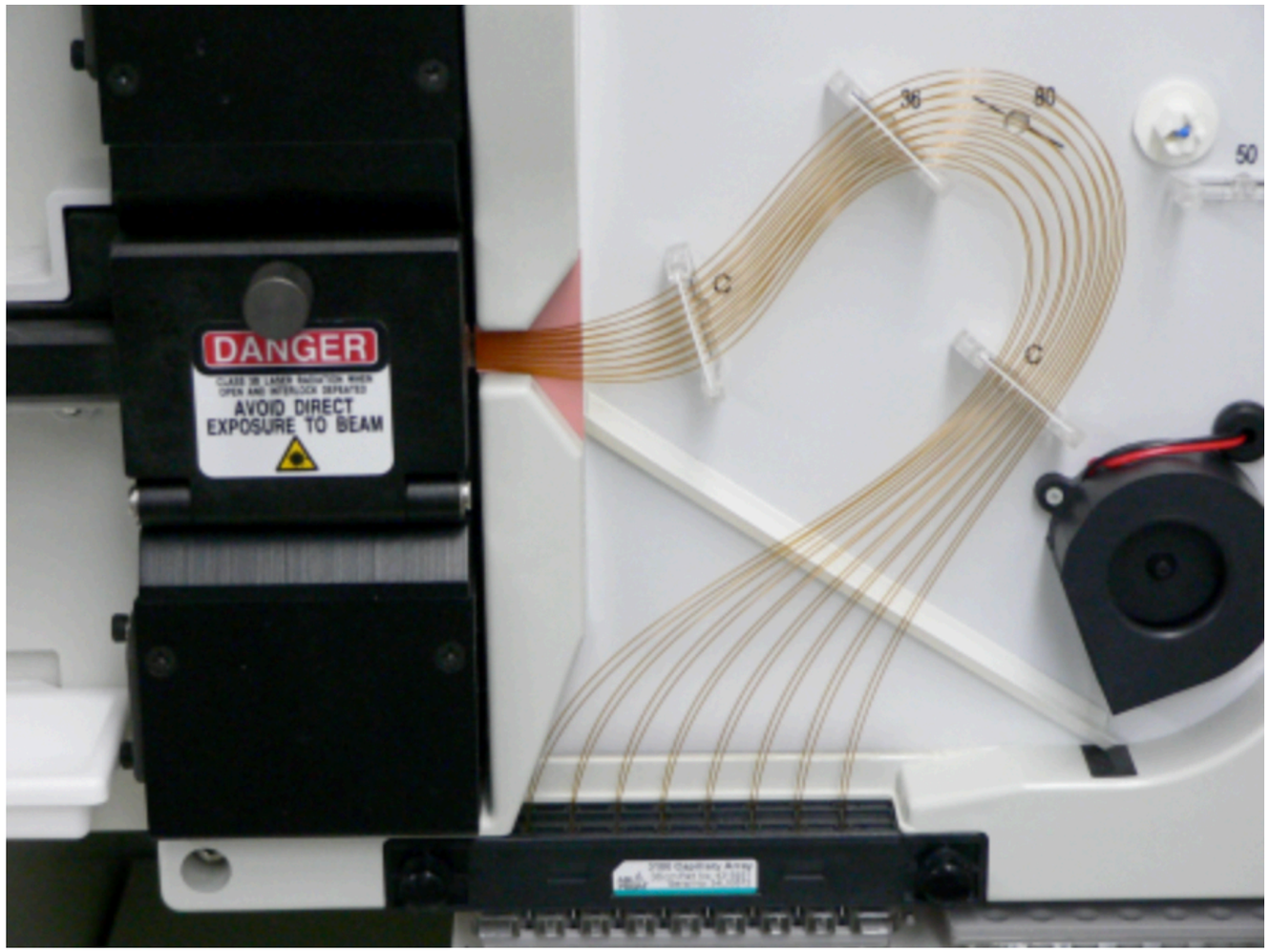


genetic analyzer: automates electrophoresis

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

DNA in Forensic Science

Workflow for analyzing DNA



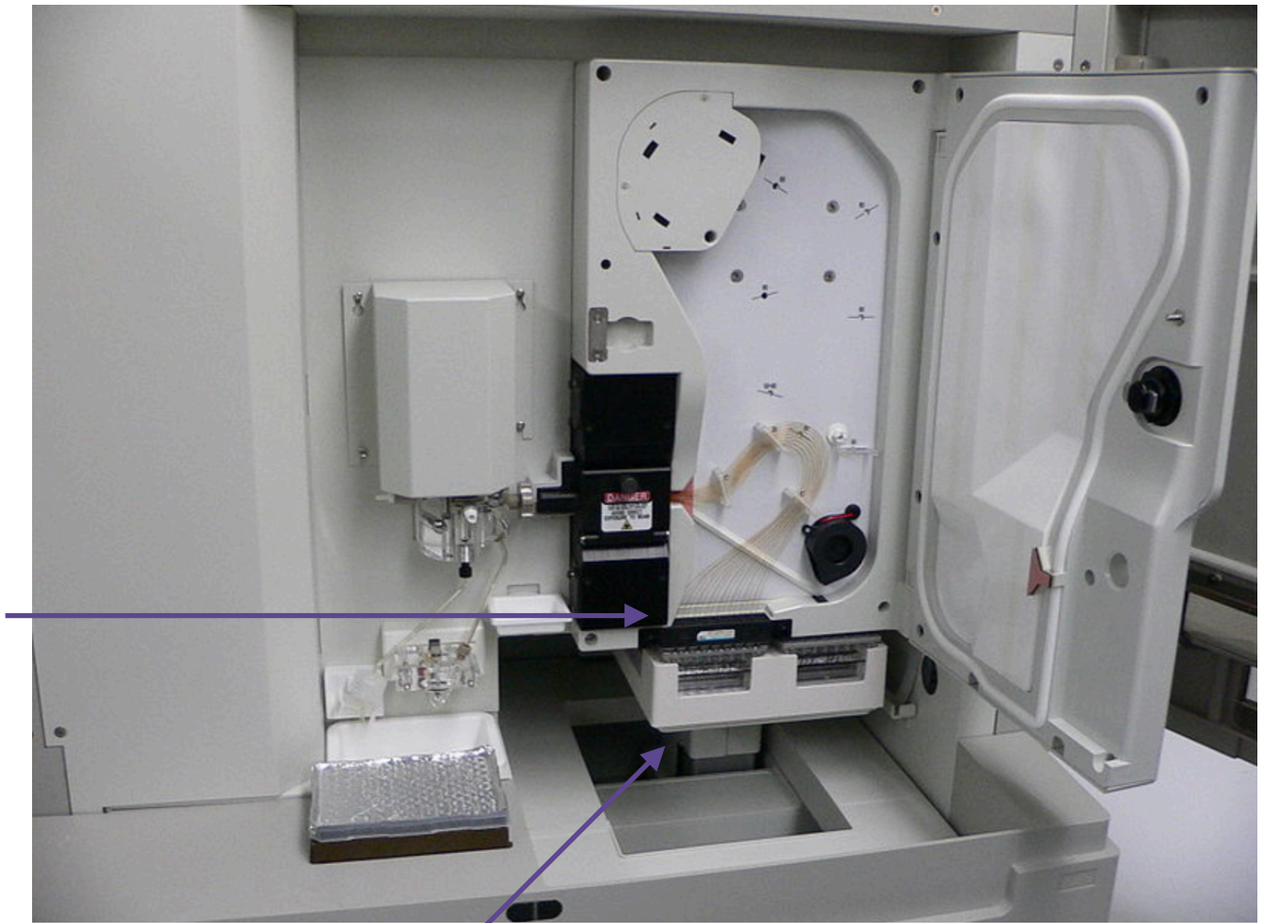
Genetic Analyzer

- runs through a capillary instead of a gel
- fluorescent tag added to the amplified DNA fragment during PCR. The tag will fluoresce in the presence of a laser
- standards are run with specific fluorescent tags so you can calibrate.

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

DNA in Forensic Science

Workflow for analyzing DNA

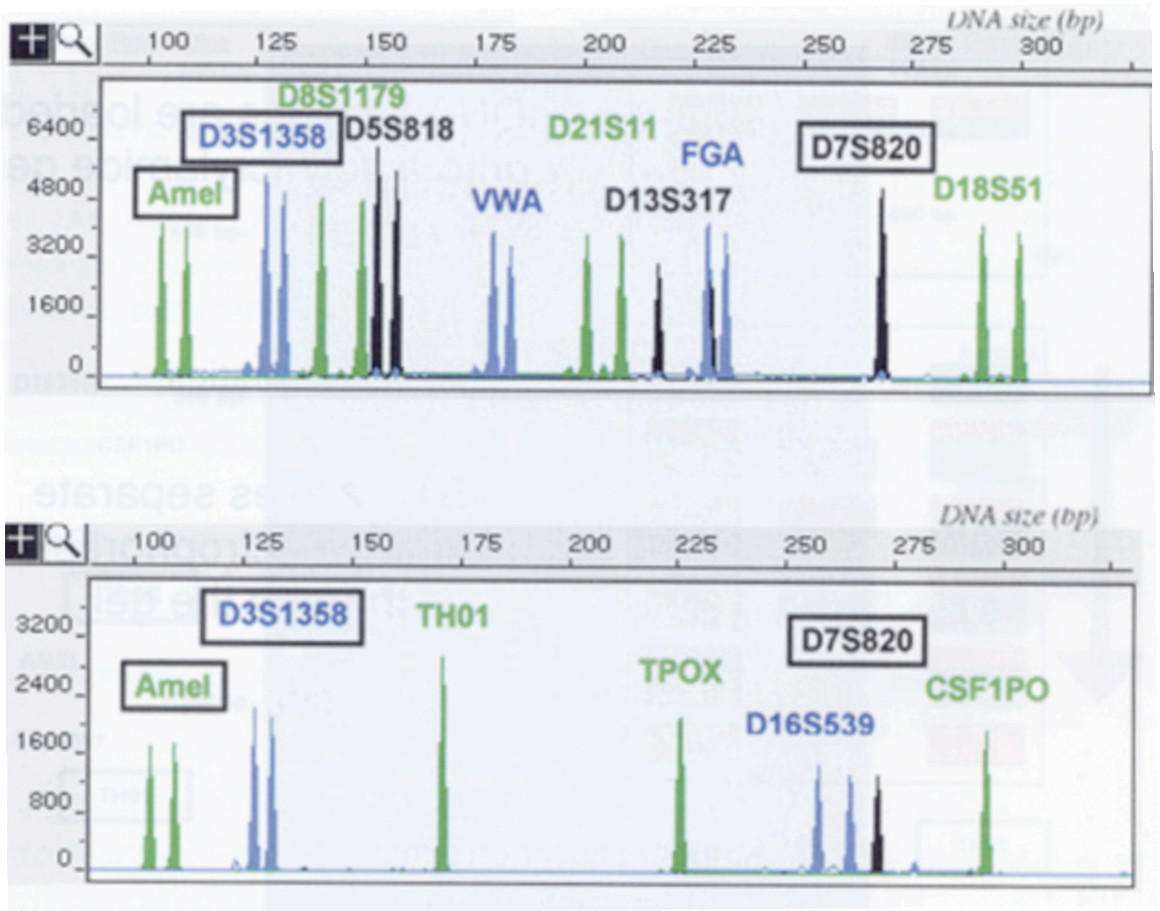


capillaries originate here

plates containing DNA are loaded at the bottom

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

DNA in Forensic Science



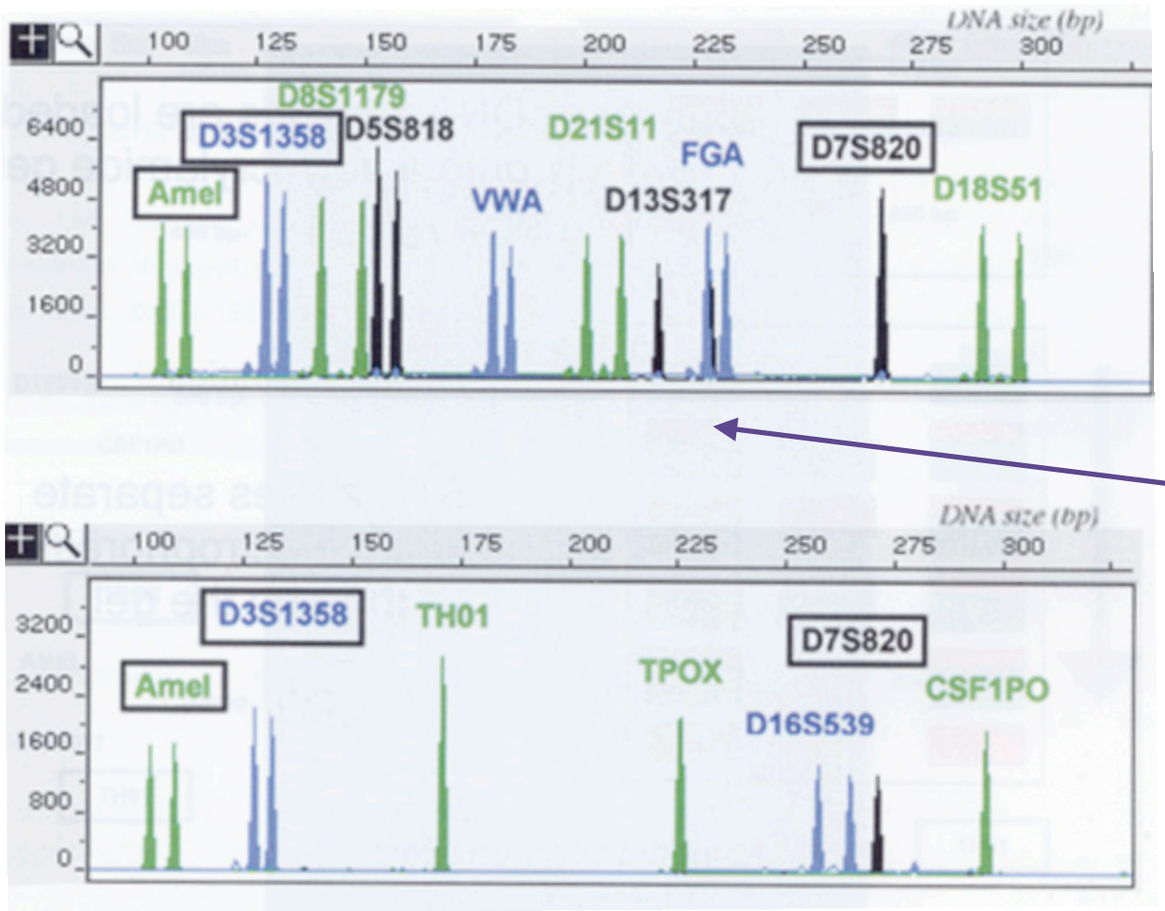
DNA marker alleles present
estimated by the use of dyes specific for the SNP or STR of interest

The dyes fluoresce, emitting light of different colors when passing through the laser.

Each time a marker passes through the laser and fluoresces, it's represented by a colored peak.

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

DNA in Forensic Science



x-axis determines size

Y axis provides information of the strength of the signal

- homozygous: height of peak is larger

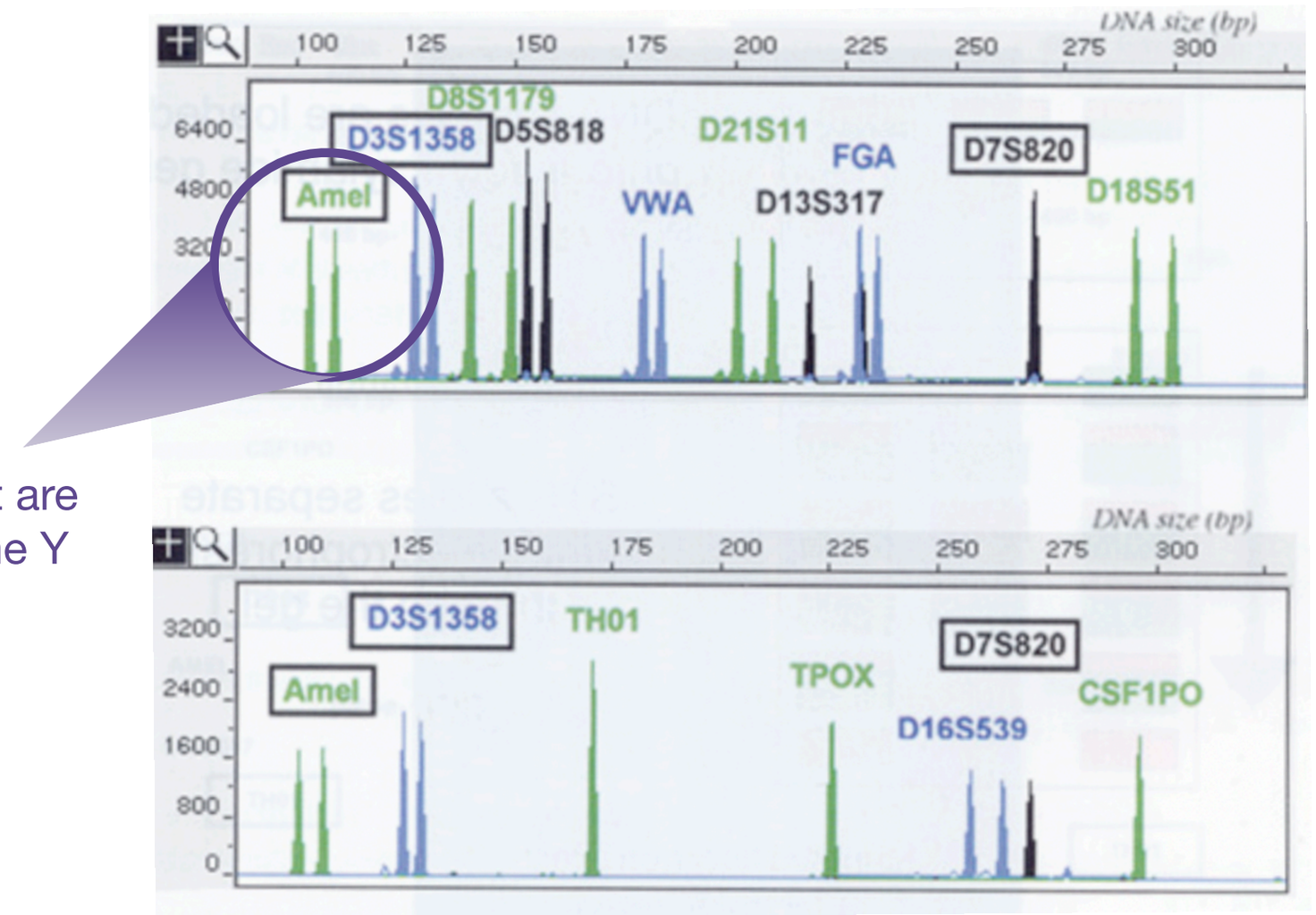
- Fragment size is represented by the location of the colored peak along the horizontal axis.

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

DNA in Forensic Science

Example: amelogenin locus (found on sex chromosomes)

y chromosome version is 6 base pairs
longer than the X chromosome version



- male: 2 medium sized peaks that are 6 base pairs apart (one X and one Y chromosome)
- female: 1 large peak (two X chromosomes)

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

DNA in Forensic Science

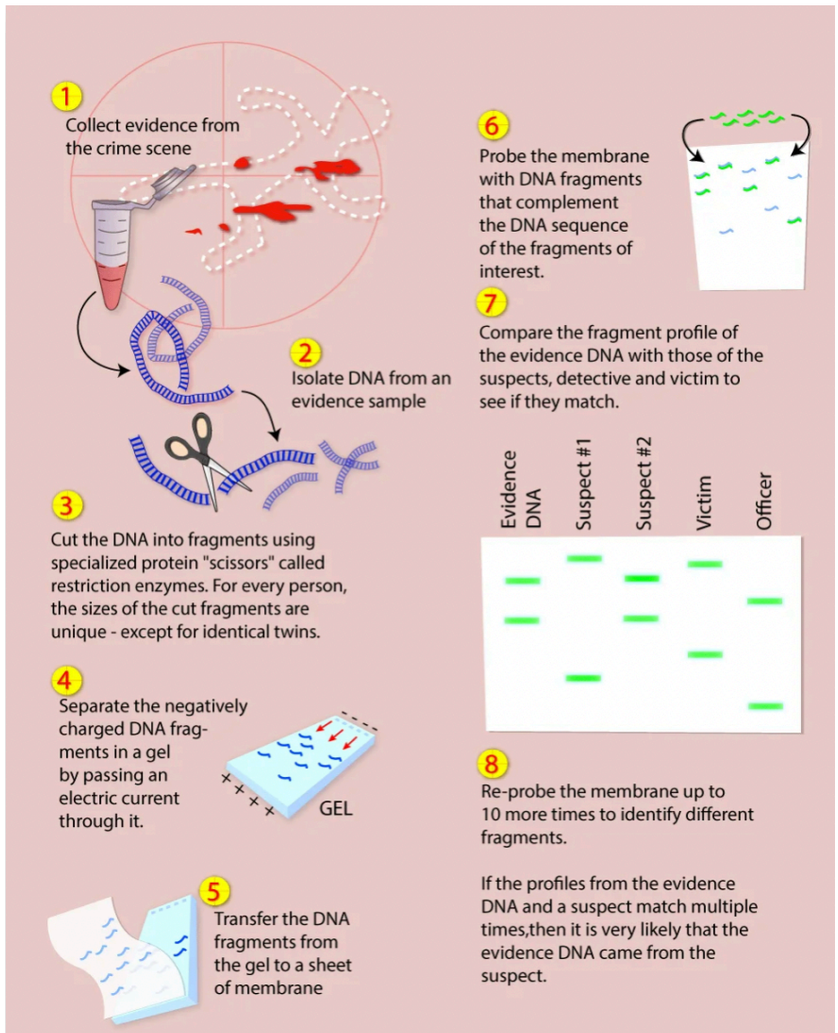
Can DNA demand a verdict?

restriction fragment length polymorphism (RFLP), shown below, is an older DNA -profiling technique that has largely been replaced by PCR

- In order to analyze a sample, enough DNA to get an accurate, quantifiable reading is needed

- In its early days, DNA analysis required an evidence sample at least the size of a dime.

Today, PCR technology allows accurate DNA analysis from very tiny amounts of material, even just from the butt of a cigarette



Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

DNA in Forensic Science

Can DNA demand a verdict?

originally known as “DNA fingerprinting”, but now known as “DNA profiling” or “DNA testing” to distinguish it from traditional skin fingerprinting

DNA Analysis’ first appearance in courtroom

1987

DNA is used in **less than 1%** of all criminal cases

Present

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

DNA in Forensic Science

Can DNA demand a verdict?

on average, any two people share 99.9% of their DNA, so only 0.1% of DNA is actually individually unique!

Remember, our DNA consists of about 3 billion base pairs, so that leaves about 3 million unique base pairs per individual

the only exception is identical twins, who share 100% of their DNA

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

DNA in Forensic Science

Can DNA demand a verdict?

What about blood relatives?

If the DNA profile from a piece of evidence is similar but not identical to that of a suspect, officials may investigate blood relatives of the suspect.

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

DNA in Forensic Science

Can DNA demand a verdict?

DNA profile

combination of alleles that is specific to a person

Crime Scene DNA

Recall match probability

the chance that a DNA profile chosen at random from the population will match that from the crime scene

- The lower the probability, the stronger the evidence that the suspect committed the crime.

STR loci are not linked = *independent evidence*

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

What is the probability of a randomly selected person having allele 10 for a particular STR locus?

probability
estimated from allele frequency in population of interest

allele frequencies
estimated from samples of the population

allele 10

STR locus CSF1PO genotype (heterozygous): alleles 10 and 11

DNA Profile		Allele frequency from database				Genotype frequency for locus	
Locus	Alleles	Times allele observed	Size of database	Frequency		Formula	Number
CSF1PO	10	109	432	*p*=	0.25	*2pq*	0.16
	11	134		*q*=	0.31		
TPOX	8	229	432	*p*=	0.53	p^2	0.28
	8						

STR locus TPOX genotype (homozygous): alleles 8 and 8

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

What is the probability of a randomly selected person having allele 10 for a particular STR locus?

allele frequencies calculated first:

P(allele 10)=p=109/432=0.25

P(allele 11)=q=134/432=0.31

P(allele 8)=p=229/432=0.53

allele frequencies
estimated from samples of the population

allele 10

DNA Profile		Allele frequency from database				Genotype frequency for locus	
Locus	Alleles	Times allele observed	Size of database	Frequency		Formula	Number
CSF1PO	10	109	432	*p*=	0.25	*2pq*	0.16
	11	134		*q*=	0.31		
TPOX	8	229	432	*p*=	0.53	p^2	0.28
	8						

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

What is the probability of a randomly selected person having allele 10 for a particular STR locus?

allele frequencies calculated first:

P(allele 10)=p=109/432=0.25

P(allele 11)=q=134/432=0.31

P(allele 8)=p=229/432=0.53

allele frequencies
estimated from samples of the population

allele 10

for heterozygous genotypes

random inheritance of a genotype 10, 11

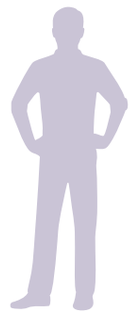
P(10,11)= 2pq = 2(0.25)0.31 = 0.16

both are plausible so must multiple by 2

allele 11
from mother

allele 10
from father

allele 10
from mother



allele 11
from father

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

What is the probability of a randomly selected person having allele 8 for a particular STR locus?

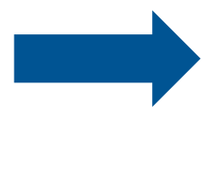
allele 8

for homozygous genotypes

random inheritance of a genotype 8 for TPOX

$P(8,8)= p(p) = p^2 = 0.16$

DNA Profile		Allele frequency from database			Genotype frequency for locus	
Locus	Alleles	Times allele observed	Size of database	Frequency	Formula	Number
CSF1PO	10	109	432	p= 0.25	$2pq$	0.16
	11	134		q= 0.31		
TPOX	8	229	432	p= 0.53	p^2	0.28
	8					



allele 8
from mother

allele 8
from father

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

What is the probability of a person having the combined genotypes of 10, 11 and 8,8 for CSF1PO and TPOX

allele 8,8

allele 10, 11

P(10,11 and 8,8)= P(10,11)*P(8,8) = random match probability (RMP)

= 0.16(0.28) = 0.045 = 4.5%

DNA Profile		Allele frequency from database				Genotype frequency for locus	
Locus	Alleles	Times allele observed	Size of database	Frequency		Formula	Number
CSF1PO	10	109	432	*p*=	0.25	*2pq*	0.16
	11	134		*q*=	0.31		
TPOX	8	229	432	*p*=	0.53	p^2	0.28
	8						

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

What is the probability of a person having the combined genotypes of 10, 11 and 8,8 for CSF1PO and TPOX

allele 8,8

allele 10, 11

P(10,11 and 8,8)= P(10,11)*P(8,8) = random match probability (RMP)

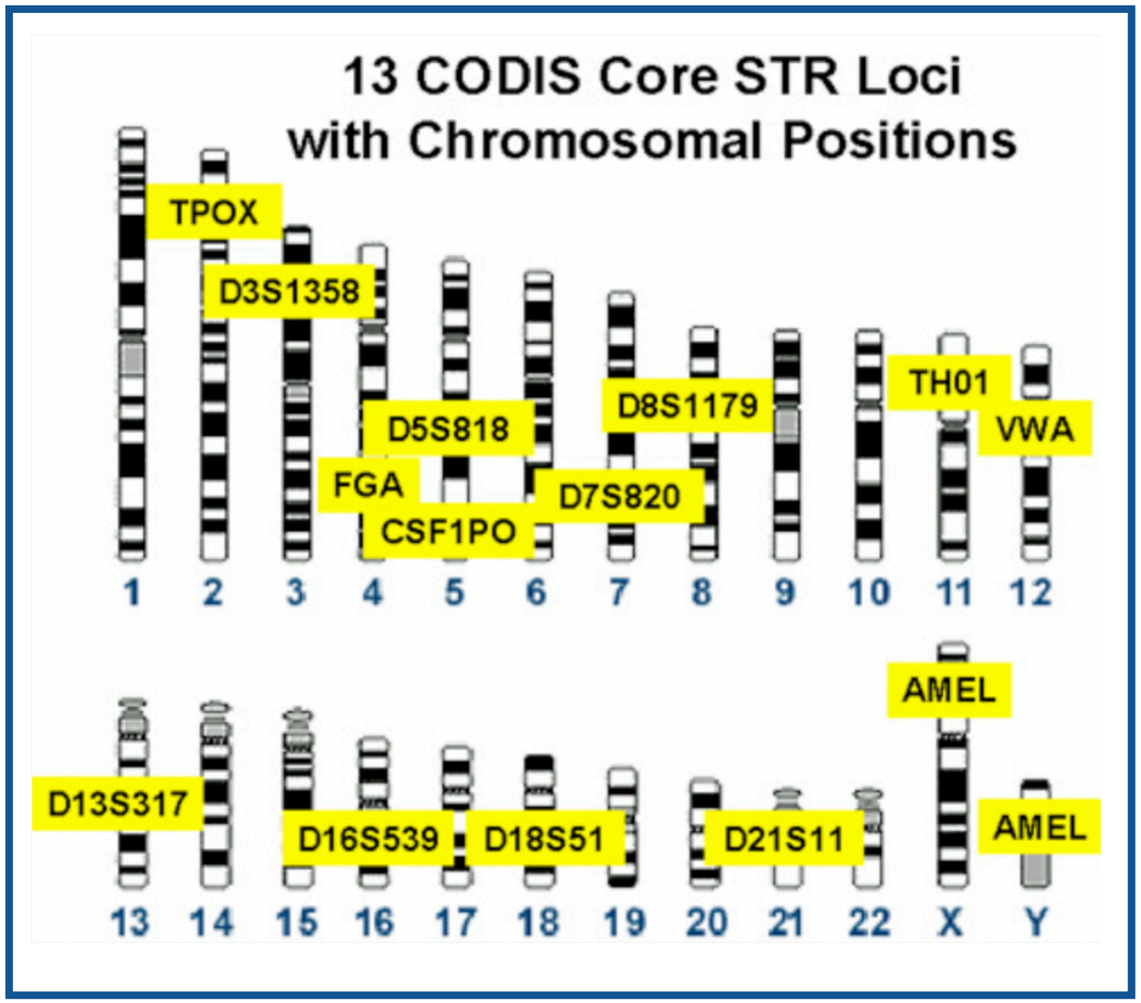
The most important concept for crime scene DNA matches!!

- must use multiple loci to get more accurate RMP and accurately pinpoint identity

acceptable RMP is $>10^{-8}$ or 0.000001%

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

***Co**mbined **D**NA **I**ndex **S**ystem*



a national and international DNA databases

searchable databases to match crime scene DNA profiles to those in the database

13 unlinked (independent) STR loci with high heterozygosity

allele sizes range from 100-400

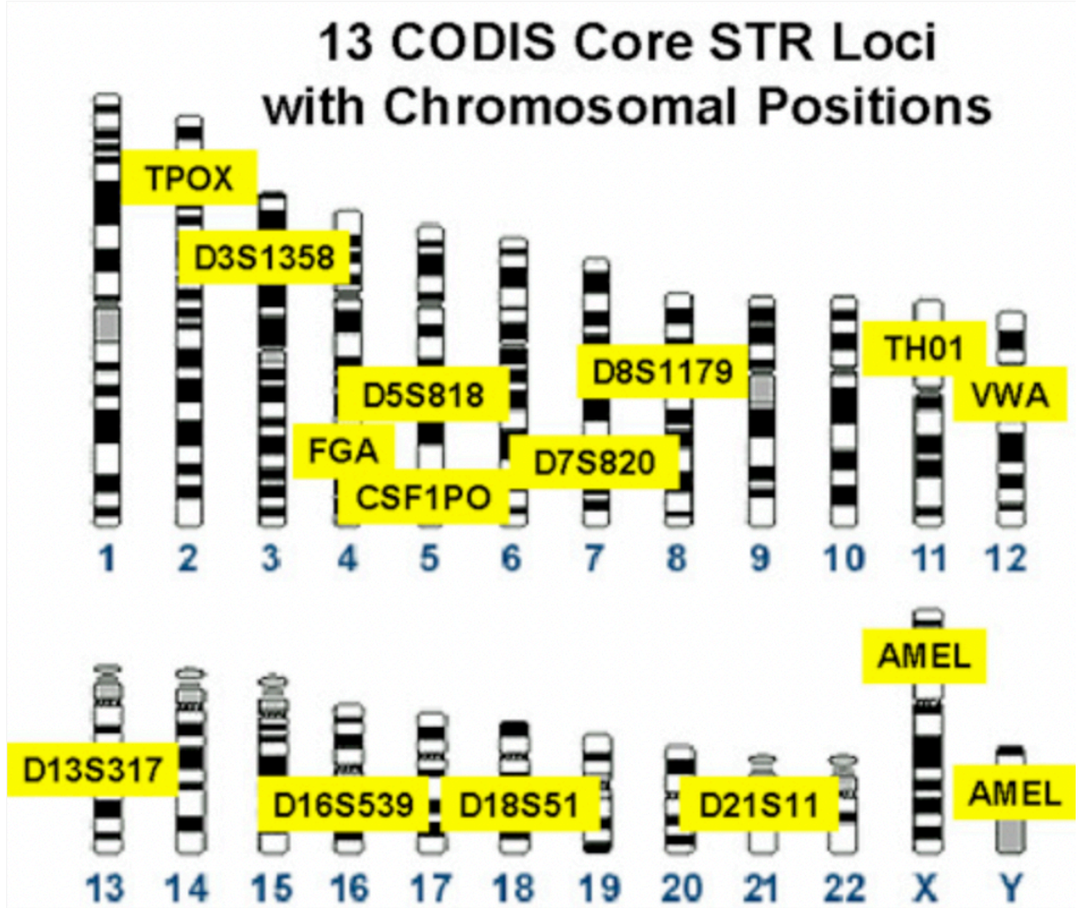
Malhi, R.; Hughes, C. (2020) *Forensic Science: History and Development*.

***Co**mbined **D**NA **I**ndex **S**ystem*

Alleles for use in forensic investigations

TPOX	D3S1358	FGA	D5S818
CSF1PO	D7S820	D8S1179	
TH01	VWA	D13S317	D16S539
D18S51	D21S11	AMEL	

**Note that almost all are on separate chromosomes*



13 unlinked (independent) STR loci with high heterozygosity

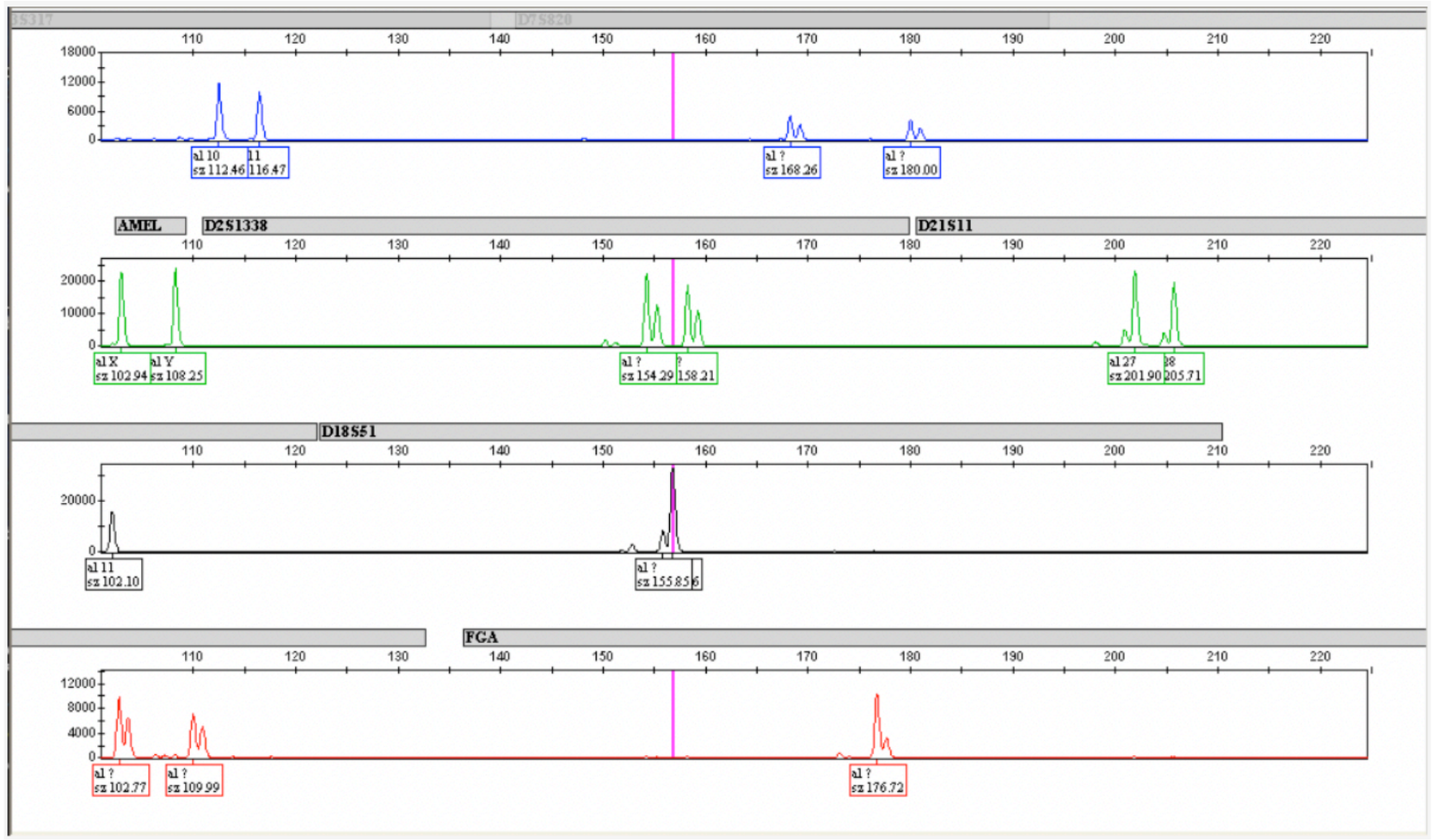
allele sizes range from 100-400

Malhi, R.; Hughes, C. (2020) *Forensic Science: History and Development*.

***Co**mbined **D**NA **I**ndex **S**ystem*

Genetic Analyzer Plot

CODIS STRs shown



Malhi, R.; Hughes, C. (2020) *Forensic Science: History and Development*.

***Co**mbined **D**NA **I**ndex **S**ystem*

CODIS STRs and nuclear DNA

can use RMP because looking at independent loci on different chromosomes

large database allows for rapid comparison to known samples

many fewer copies of nuclear DNA than mtDNA in a forensic sample

challenging to analyze nuclear DNA in small or damaged samples

mtDNA

thousands more copies of mtDNA than nuclear DNA in a sample

ideal for maternal line blood-relation analysis

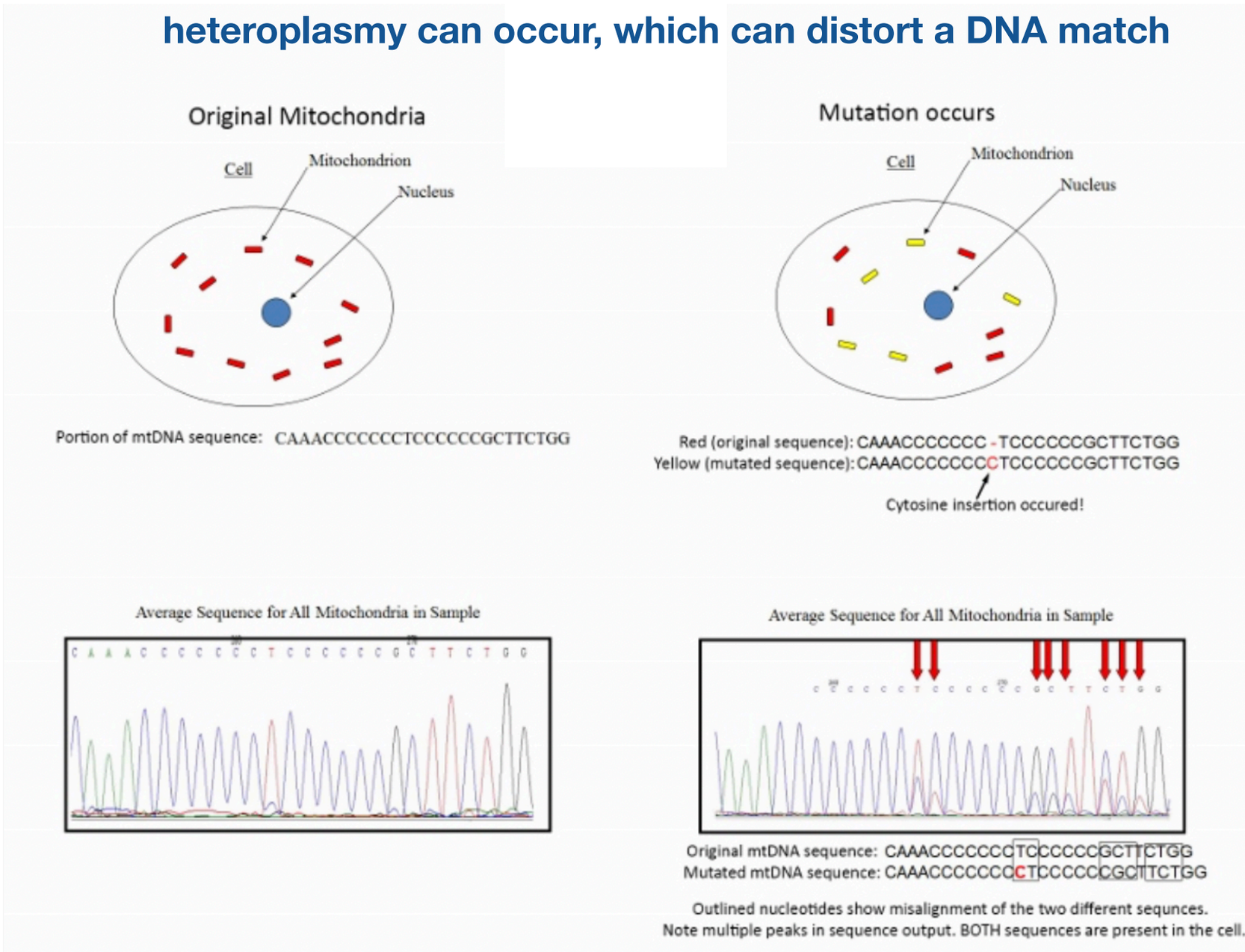
limited amount of variation (many people share identical mtDNA

not ideal for getting acceptable levels of RMP- mtDNA is not independent

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

DNA in Forensic Science

heteroplasmy can occur, which can distort a DNA match

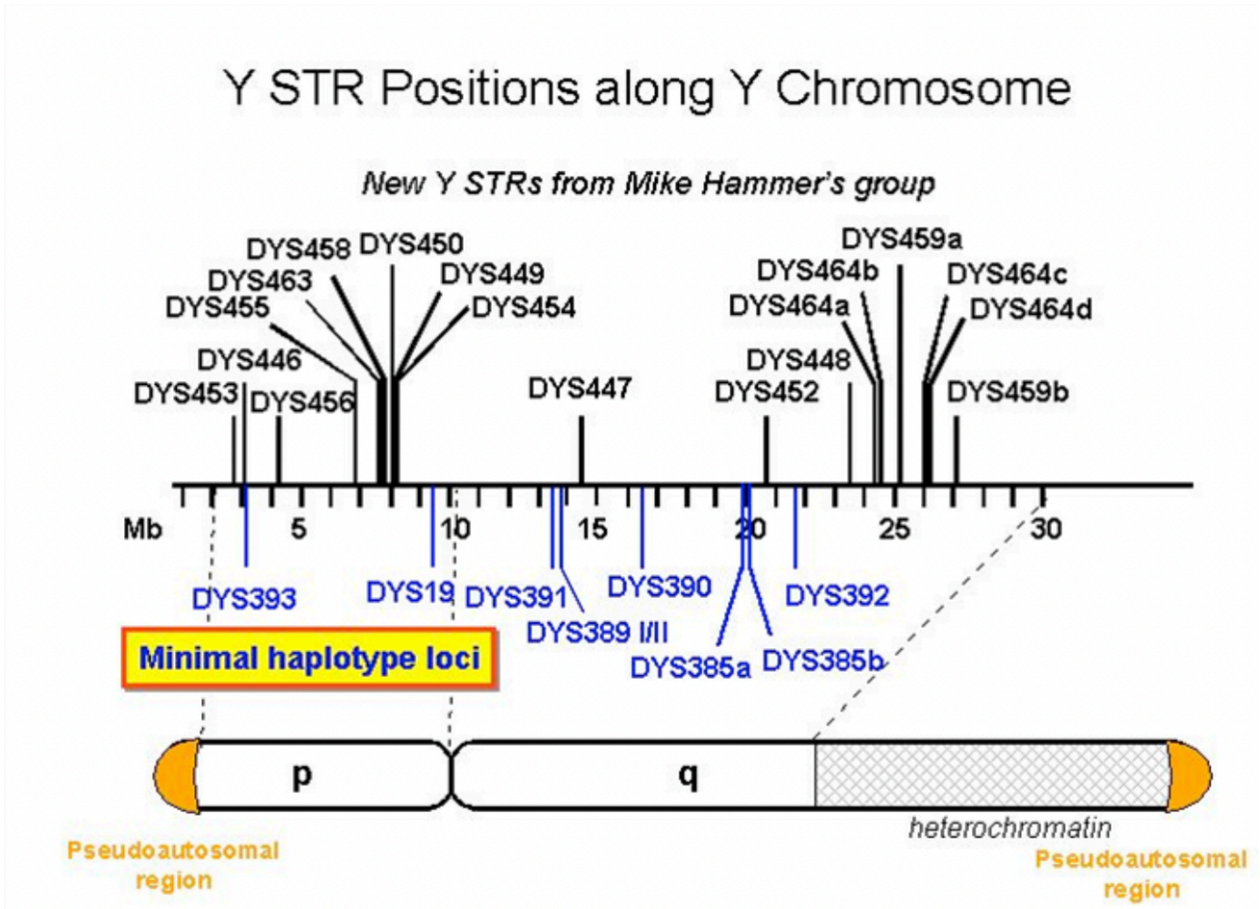


specific to the individual with the mutation (and then their offspring

common in hair shaft samples

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

Y Chromosome STRs



paternally inherited only
used for paternity testing, genealogy DNA testing, and forensics matching

inherited directly from father so no variation from parent to offspring

can be used successfully for exclusion tests

If son has different STRs than father, paternity can be ruled out

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

Y Chromosome STRs

Paternity tests using DNA analysis

uses up to 15 DNA markers (including the CODIS markers)

can be used successfully for exclusion tests

If son has different STRs than father,
paternity can be ruled out

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

Y Chromosome STRs

Paternity tests using DNA analysis

uses up to 15 DNA markers (including the CODIS markers)

Locus	Alleged Father	Child	Parentage Index
D2S1338	12, 13	8, 9	0.00
D2S1358	8, 11	13, 14	0.00
D8S1179	21.2, 32	19, 21.2	0.675
D10S1008	7, 12	15, 18	0.00
D14S1537	9, 14	11, 14	0.797
D19S433	15, 18	12, 15	1.338

can be used successfully for exclusion tests

If son has different STRs than father, paternity can be ruled out

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

Y Chromosome STRs

Paternity tests using DNA analysis

uses up to 15 DNA markers (including the CODIS markers)

Locus	Alleged Father	Child	Parentage Index
D2S1338	12, 13	8, 9	0.00

In this example, the alleged father and child both have a matching allele (allele 12)

Parentage Index is a measure of how common a match between allele 12 would be

larger PI= a more rare allele, higher likelihood there is a match

can be used successfully for exclusion tests

If son has different STRs than father, paternity can be ruled out

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

Y Chromosome STRs

Paternity tests using DNA analysis

uses up to 15 DNA markers (including the CODIS markers)

Locus	Alleged Father	Child	Parentage Index
D2S1338	12, 13	10, 12	1.845
D2S1358	8, 11	11, 14	2.714
D8S1179	21.2, 32	19, 21.2	3.675
D19S433	15, 18	12, 15	8.338
Combined Parentage Index (CPI):			153.435
Probability of Paternity:			99.348%

Combined Parentage Index must reach 100 for a match

correlates to a probability of paternity of 99.0000%

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

Y Chromosome STRs

How can you analyze data in cases where crime scene samples are mixtures of victim and assailant's DNA?

autosomal STRs and mtDNA for the victim and the assailant will be mixed in the sample and challenging to decipher

XX chromosomes

XY chromosomes

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

Y Chromosome STRs

Crime Scene DNA

Recall match probability

the chance that a DNA profile chosen at random from the population will match that from the crime scene

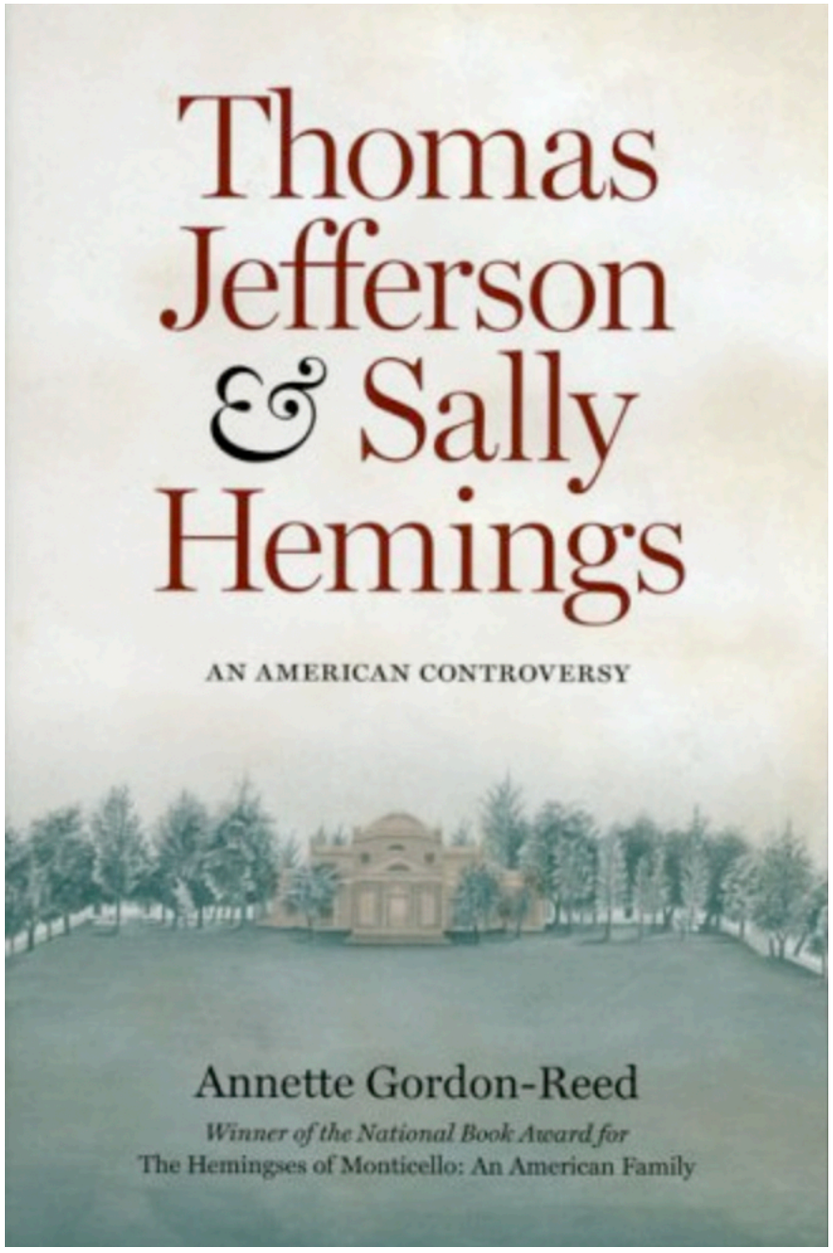
Y Chromosome analysis has similar issue as mtDNA for RMPs

violates assumptions of random and independent variables

Malhi, R.; Hughes, C. (2020) *DNA Evidence*.

Y Chromosome STRs

Case study: Thomas Jefferson Paternity Scandal



Paternity of Easton Hemmings was hypothesized to be owner, Thomas Jefferson

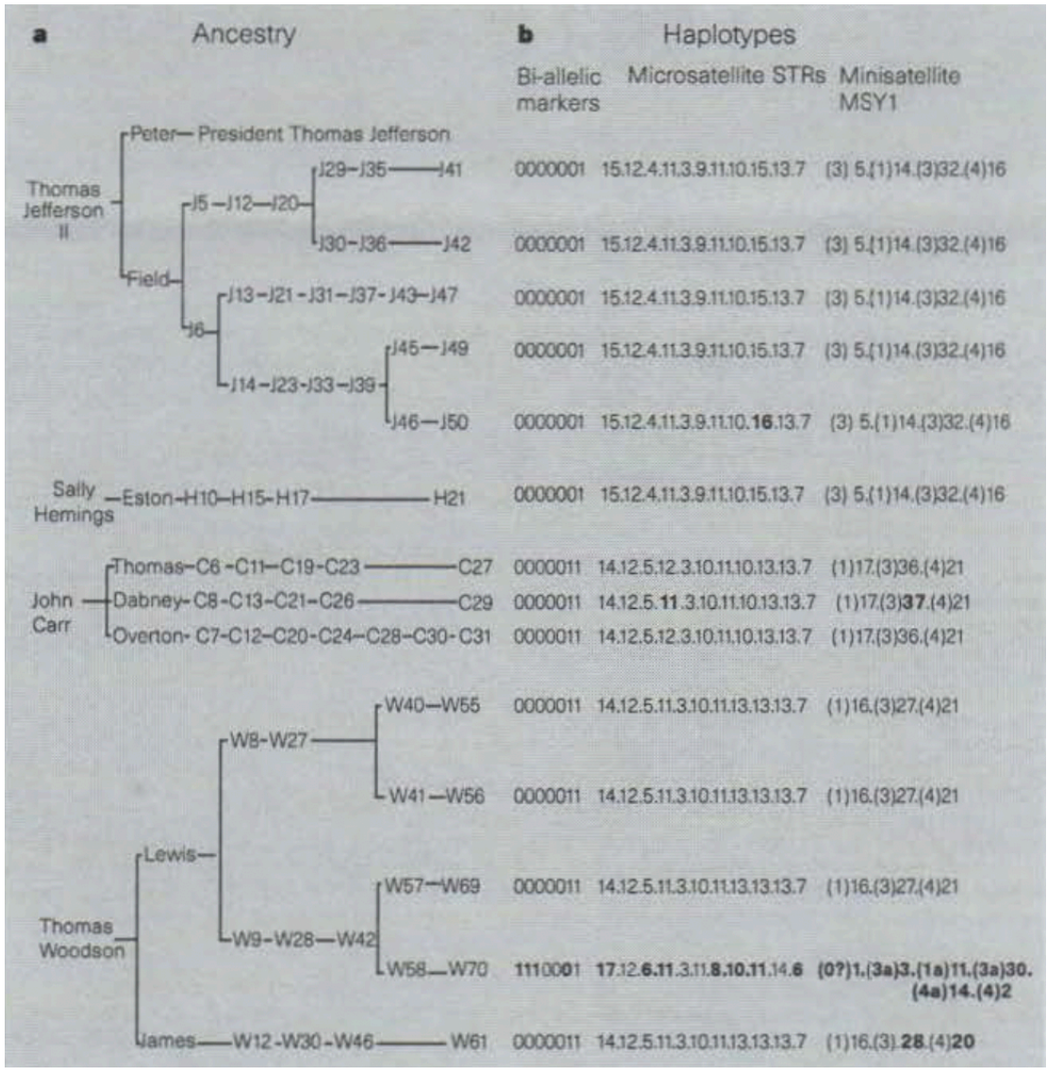
- Written record also suggested Samuel Carr, a son of President Jefferson's sister, as the father

- Jefferson had no confirmed, living male children, so a paternal uncle of the President, Field Jefferson, was compared.

Foster, E.; Jobling, M.; Taylor, P.; Donnelly, P.; Knijff, P.; Mieremet, R.; Zerjal, T.; Tyler-Smith, C. *Nature* **1998**, *396*, 27.

Y Chromosome STRs

Case study: Thomas Jefferson Paternity Scandal



Paternity of Easton Hemmings was hypothesized to be owner, Thomas Jefferson

- Y chromosome analysis ruled out Carr and confirmed a Y chromosome from the male Jefferson line

DNA analysis of family lines is incredibly powerful!

Foster, E.; Jobling, M.; Taylor, P.; Donnelly, P.; Knijff, P.; Mieremet, R.; Zerjal, T.; Tyler-Smith, C. *Nature* **1998**, *396*, 27.

DNA in Forensic Science

We have talked about how powerful DNA evidence is, but is it also fallible?

DNA in Forensic Science

“in the three decades since DNA emerged as a forensic tool, courts have rarely been skeptical about its power. When the technique of identifying people by their genes was invented, it seemed like just the thing the rustic system had always been waiting for: Bare, scientific fact that could circumvent the problems of human perception, motivation, and bias.”

“a mystical aura of definitiveness often surrounds the value of DNA evidence,”

“In most cases, this aura is deserved. The method is unequivocal when it tests a large quantity of one person’s well-preserved genes, when it’s clear how that evidence arrived at a crime scene, and then the lab makes no errors in its work.”

DNA in Forensic Science

Case Study 1: Conviction of Lukis Anderson

homeless individual living in San Jose, California

charged with the murder of Raveesh Kumra, a 66 year old investor in silicon Valley

His DNA was found under Kumra's fingernails, but does this prove he did it?

It was later determined that he was in a hospital the entire night of the murder.

Worth, K. (2018) *Framed for Murder by his Own DNA.*

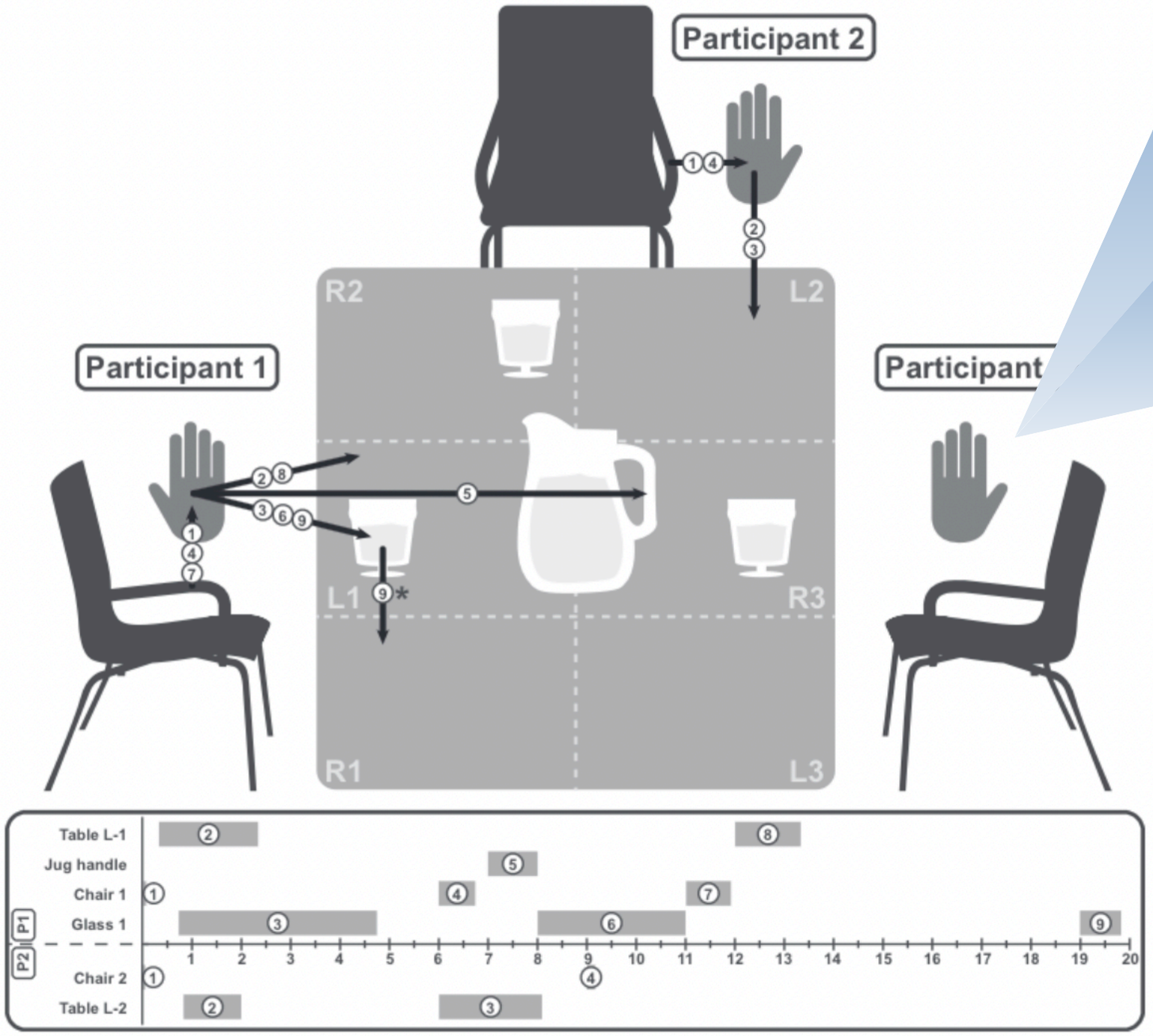
DNA in Forensic Science

Case Study 1: Conviction of Lukis Anderson

Study in *Nature* found that objects handled event transiently can possess enough DNA to get an accurate DNA profile

Oorschot, R.; Jones, M. *Nature* **1997**, *387*, 767.

DNA in Forensic Science



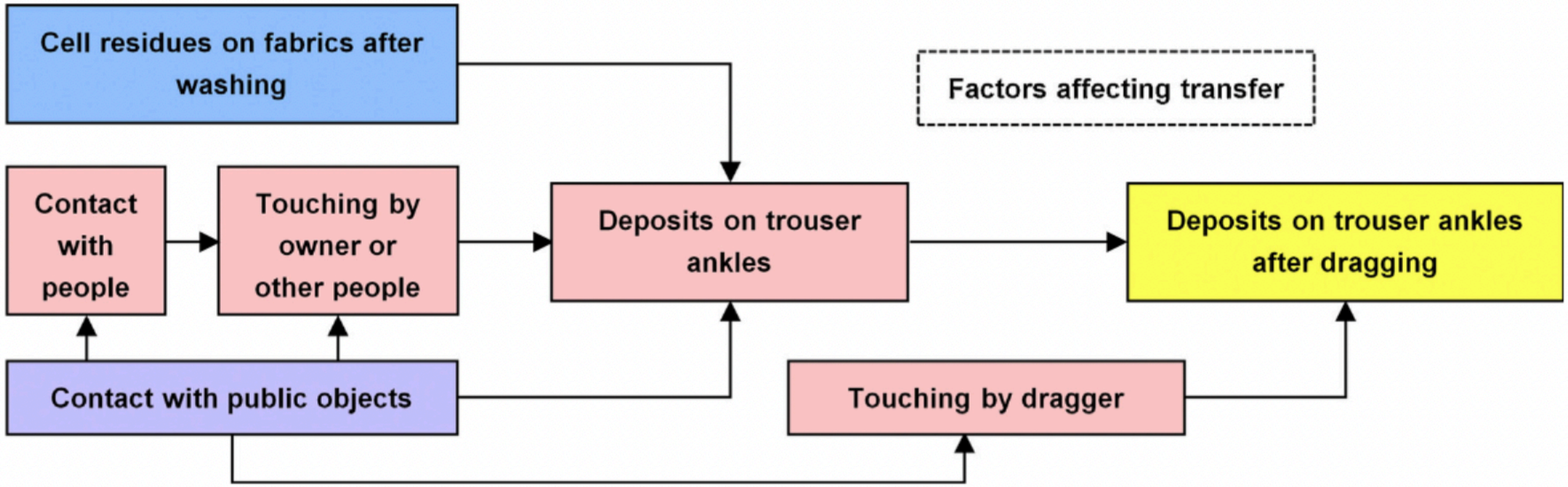
Even if participants did not touch each other, they were still found to have each other's DNA on them!

DNA was found on surfaces that did not belong to any participant!

Goray, M.; Oorschot, R. *Legal Medicine* ***2015***, *17*, 82.

DNA in Forensic Science

Can we systematically study transient DNA transfer?



Public Items

Private Samples

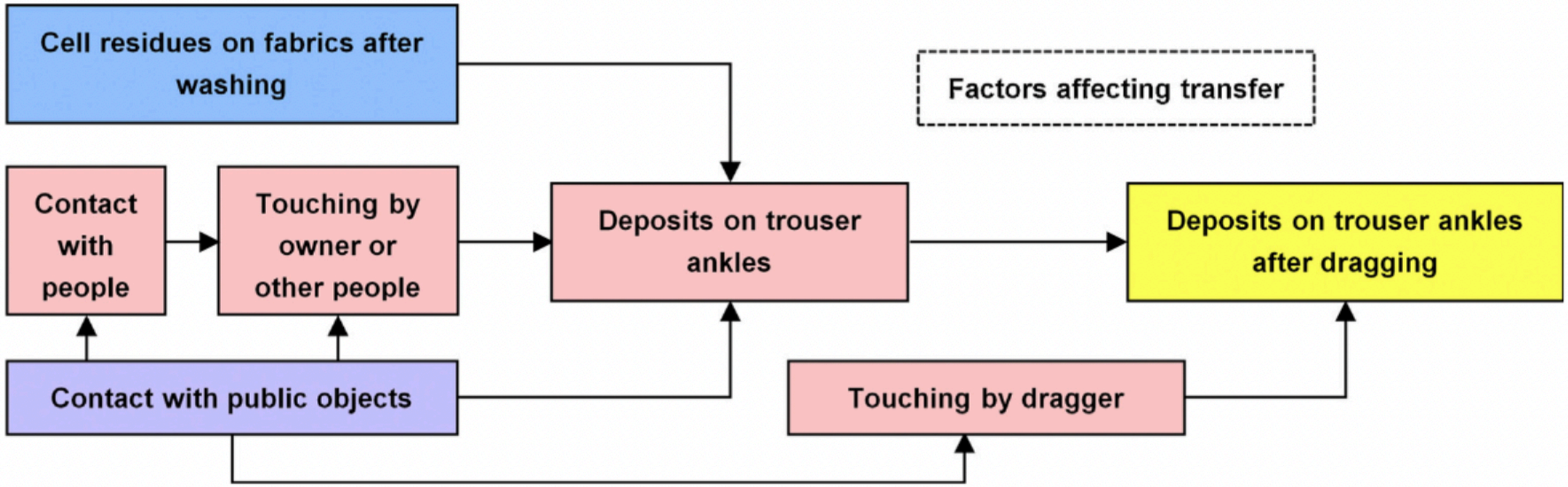
Activity-Related Samples

Washing Machine Samples

Berge, M.; Ozcanhan, G.; Zijlstra, S.; Lindenbergh, A.; Sijen, T. *Forensic Science International: Genetics* ***2016***, *21*, 81.

DNA in Forensic Science

Can we systematically study transient DNA transfer?



Public Items

Private Samples → non-owner alleles observed in 90% of cases!!

Activity-Related Samples

Washing Machine Samples

Berge, M.; Ozcanhan, G.; Zijlstra, S.; Lindenbergh, A.; Sijen, T. *Forensic Science International: Genetics* ***2016***, *21*, 81.

DNA Evidence and Forensic Anthropology

What other fields of forensic science is understanding DNA analysis critical for?

Nobel Prize in Medicine/Physiology 2022

Svante Pääbo, 2022

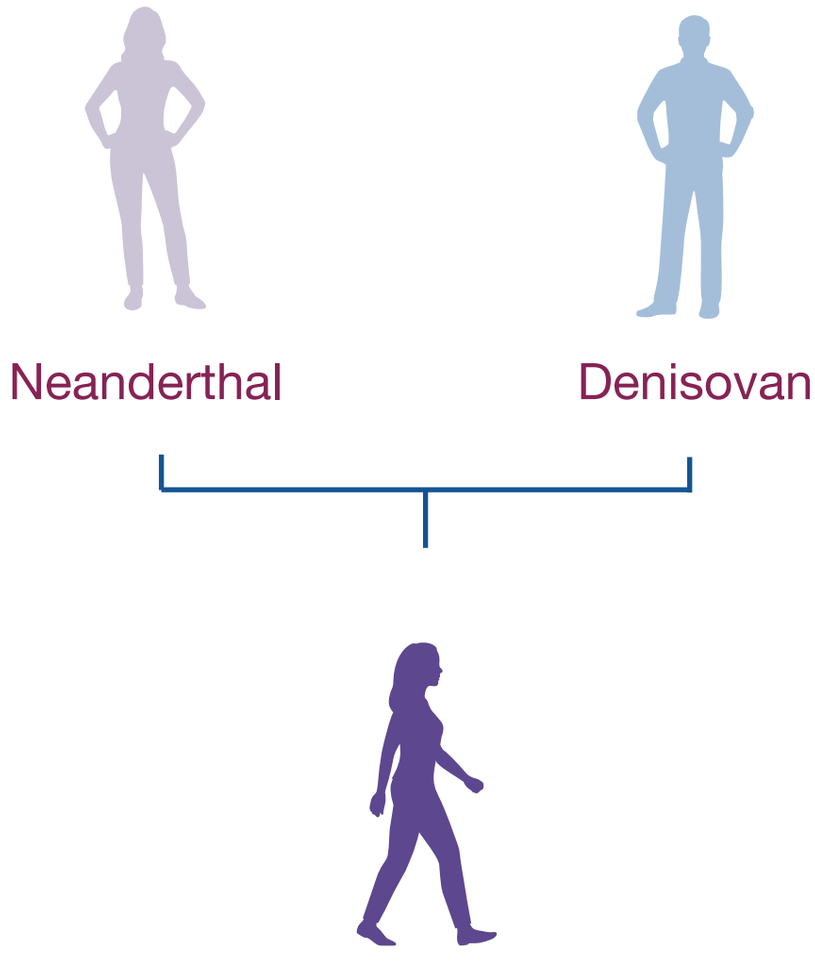
“for his discoveries concerning the genomes of extinct hominids and human evolution.”

IN DEPTH | EVOLUTION

Ancient DNA reveals tryst between extinct human species

Woman had a Neanderthal mother and a Denisovan father.

Bone of a young female unearthed from Russia's Denisova valley in 2012



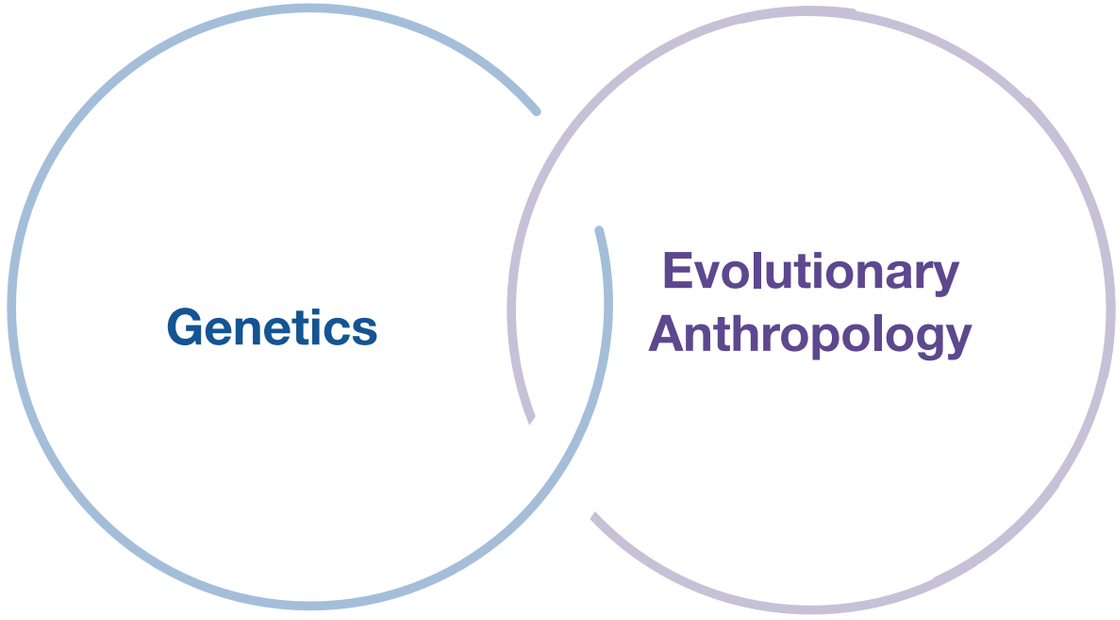
Nobel Prize in Medicine/Physiology 2022

IN DEPTH | EVOLUTION

Ancient DNA reveals tryst between extinct human species

Woman had a Neanderthal mother and a Denisovan father.

Bone of a young female unearthed from Russia's Denisova valley in 2012



DNA in Forensic Science

So what are our takeaways for forensic analysis of DNA?

Outline for the talk

- **Analytical Chemistry**
- **DNA in Forensic Science**
- **Fingerprinting**
- **Forensic Specialties**

Outline for the talk

- Analytical Chemistry
- DNA in Forensic Science
- **Fingerprinting**
- Forensic Specialties

Fingerprint analysis

Fingerprints are a reproduction of skin ridges found on the palm side of the fingers and thumbs

dactylocopy: the study of fingerprints, the most common form of lophoscopy

lophoscopy: identification and classification of the marks left by the papillary ridges of the skin

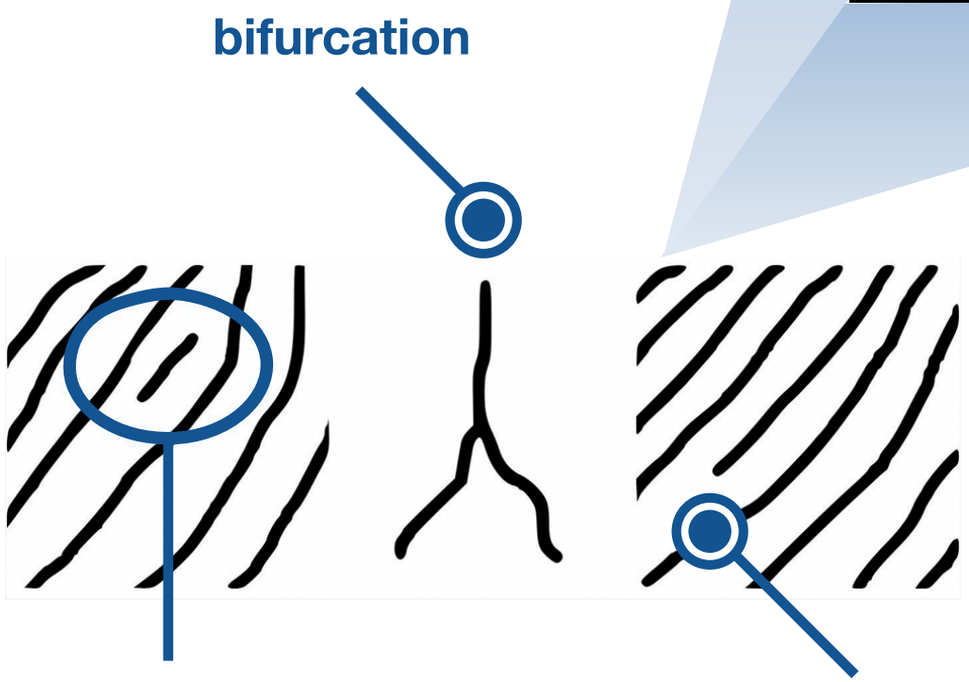
traditional fingerprint principles in criminal investigations

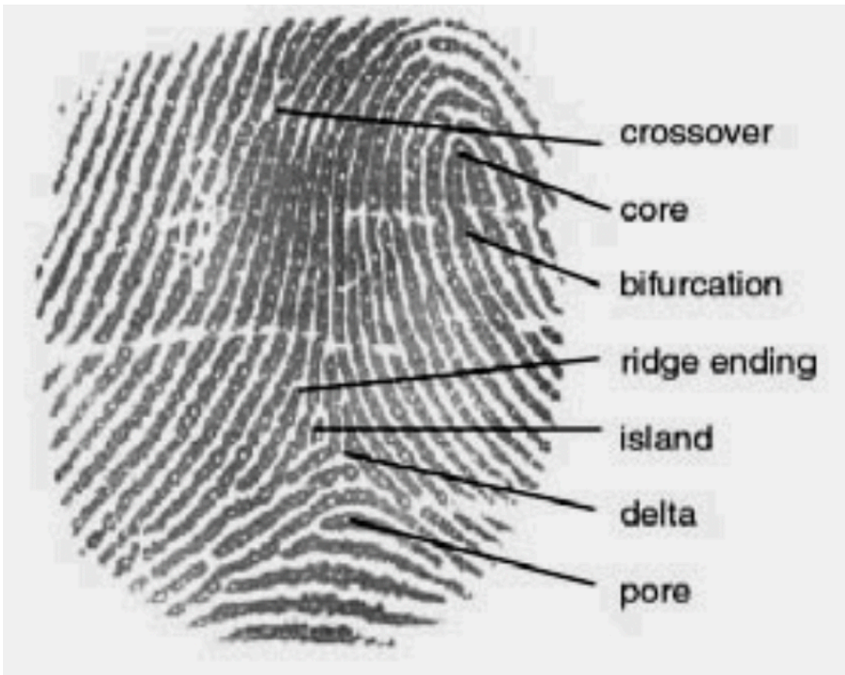
- fingerprints have general ridge patterns that permit them to be systematically classified
- a fingerprint is an individual characteristic: no two fingerprints are identical
- a fingerprint remains unchanged during an individual's lifetime

Malhi, R.; Hughes, C. (2020) *Fingerprints and Bloodstain Analysis*.

Fingerprint analysis

Fingerprints are a reproduction of skin ridges found on the palm side of the fingers and thumbs

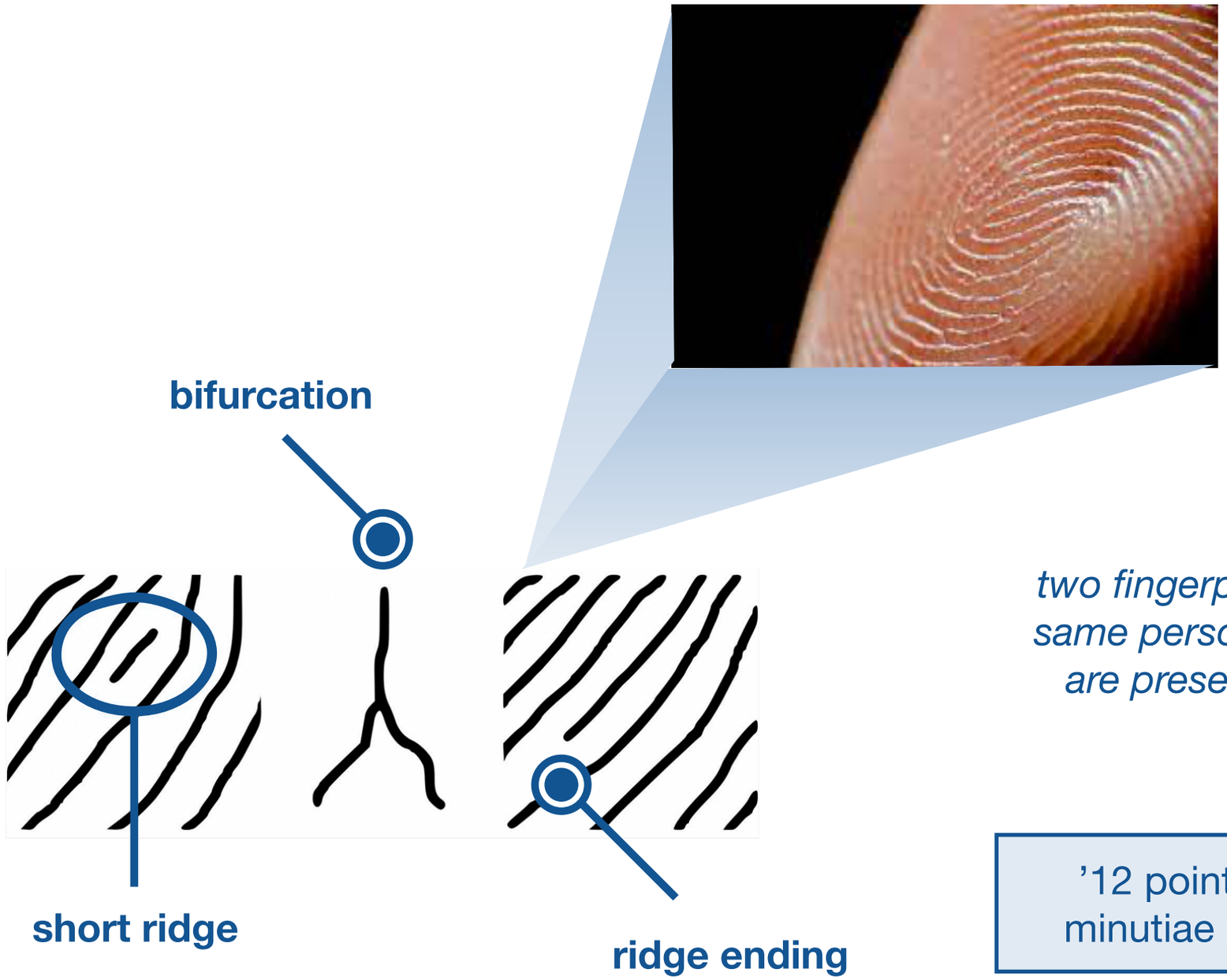




Malhi, R.; Hughes, C. (2020) *Fingerprints and Bloodstain Analysis*.

Fingerprint analysis

Fingerprints are a reproduction of skin ridges found on the palm side of the fingers and thumbs



two fingerprints are considered to be from the same person if a sufficient number of minutiae are present and there are no unexplainable differences

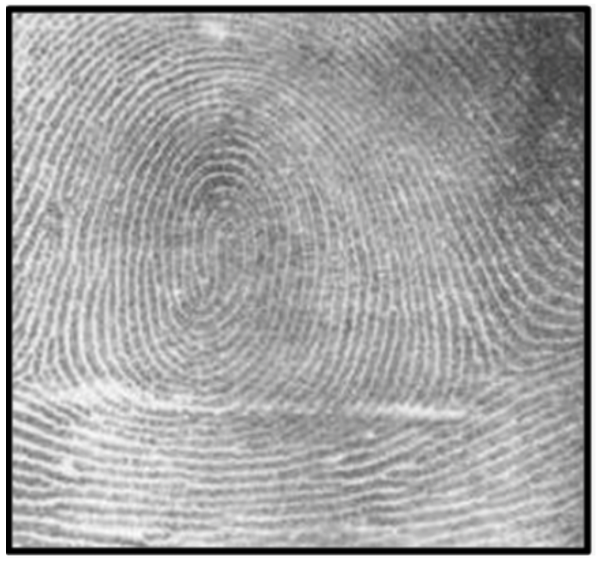
’12 points’: benchmark for the number of minutiae required for conclusion of identity

Malhi, R.; Hughes, C. (2020) *Fingerprints and Bloodstain Analysis*.

Fingerprint analysis

Loop

Arch



Whorl

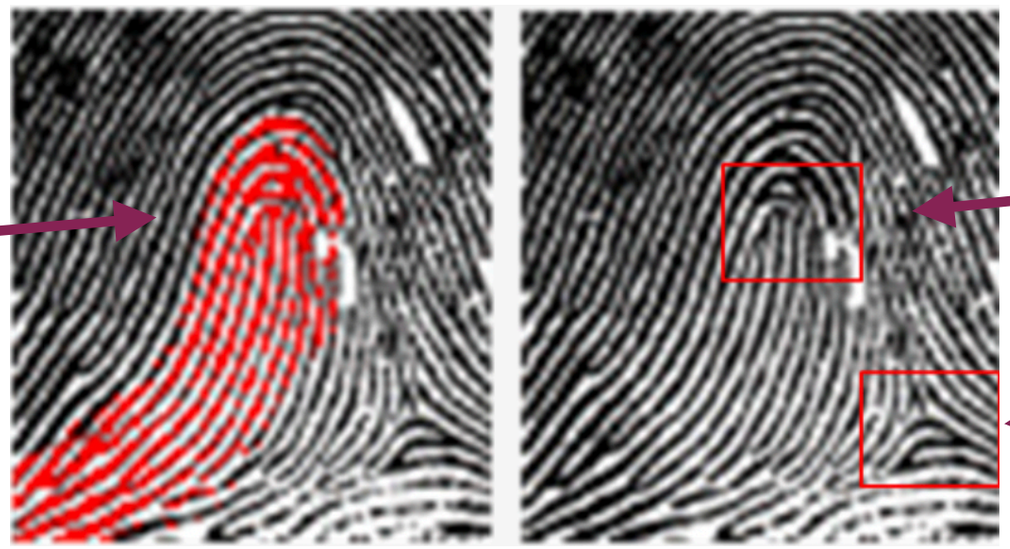
Malhi, R.; Hughes, C. (2020) *Fingerprints and Bloodstain Analysis*.

Fingerprint analysis

Loop

Double Loop Whorl

~65% of the population have loop fingerprints



ridges

characterized by a ridge that enters from one side and exits on the same side

core

delta

loops have 1 delta (where two ridges meet)

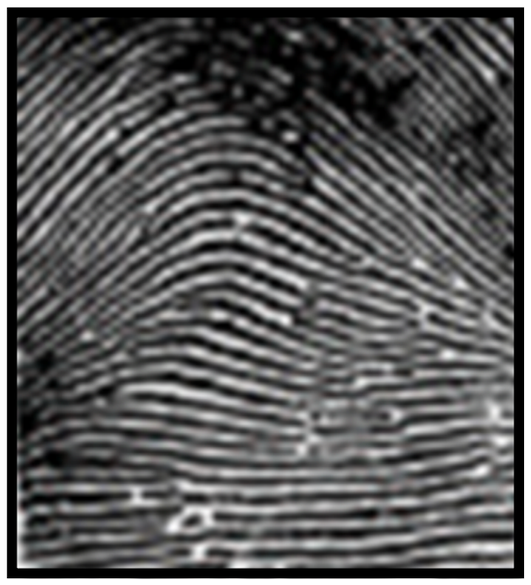
Malhi, R.; Hughes, C. (2020) *Fingerprints and Bloodstain Analysis*.

Fingerprint analysis

Arch

~5% of the population have arch fingerprints

- have ridges that enter one side and exit the other side
- tented arches have a more angled ridge

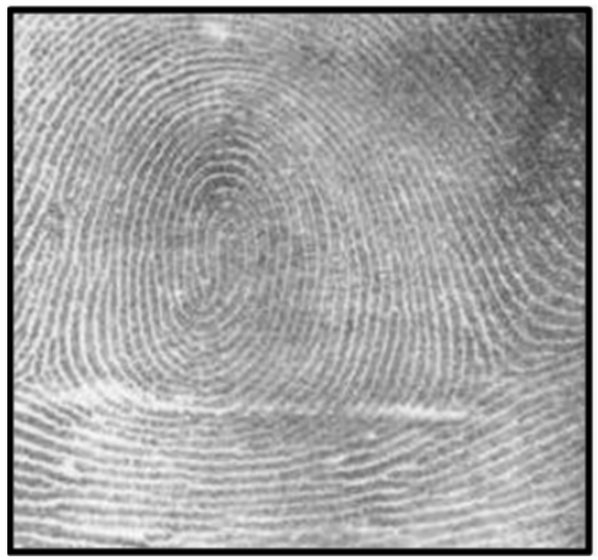


Plain arch

tented arch

Malhi, R.; Hughes, C. (2020) *Fingerprints and Bloodstain Analysis*.

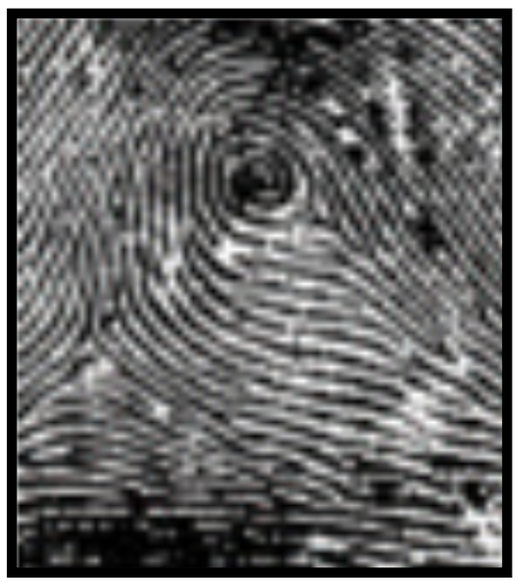
Fingerprint analysis



Whorl

~30% of the population have whorl fingerprints

- whorls have two deltas, and most have ridges that form a continuous circuit between the deltas



Central pocket whorl

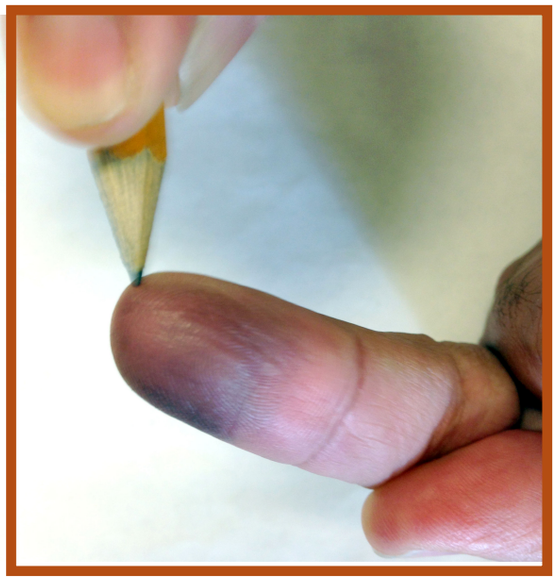
accidental whorl

plain whorl

Malhi, R.; Hughes, C. (2020) *Fingerprints and Bloodstain Analysis*.

Fingerprint analysis

Simple Fingerprinting workflow



coat finger in fingerprinting agent

press and remove adhesive strip

transfer to paper

my actual fingerprint!

smudged, cannot see all minutiae

Malhi, R.; Hughes, C. (2020) *Fingerprints and Bloodstain Analysis*.

Fingerprint analysis

Simple Fingerprinting workflow

coat finger in fingerprinting agent

transfer to paper

how can we increase detail and resolution?

my actual fingerprint!

smudged, cannot see all minutiae

Malhi, R.; Hughes, C. (2020) *Fingerprints and Bloodstain Analysis*.

Fingerprint analysis

Automated Fingerprint Identification System (AFIS)

utilizing the ability of a computer to scan and digitally encode fingerprints so that they can be subject to high-speed computer processing

Malhi, R.; Hughes, C. (2020) *Fingerprints and Bloodstain Analysis*.

Fingerprint analysis

Automated Fingerprint Identification System (AFIS)

converts the image of a fingerprint into digital minutiae

Very powerful tool! A print can be taken from a crime scene and compared to a national database

Malhi, R.; Hughes, C. (2020) *Fingerprints and Bloodstain Analysis*.

Fingerprint analysis

There are 3 types of fingerprints that can be found at a crime scene

visible print
the finger deposits a visible material (blood, ink, etc.) onto a surface

plastic print
a fingerprint impressed in a soft surface
(soap, putty, etc.)

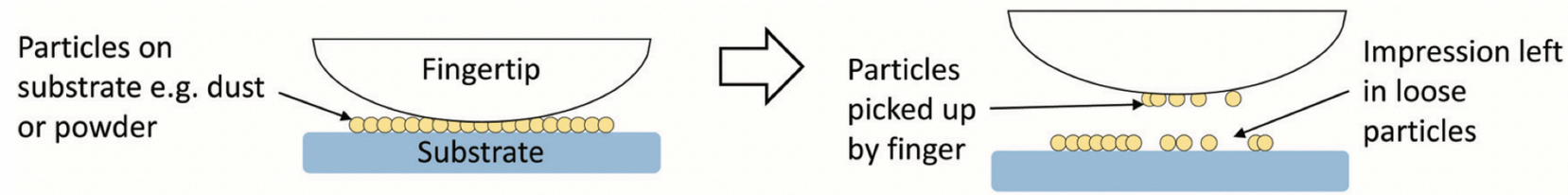
Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

There are 3 types of fingerprints that can be found at a crime scene

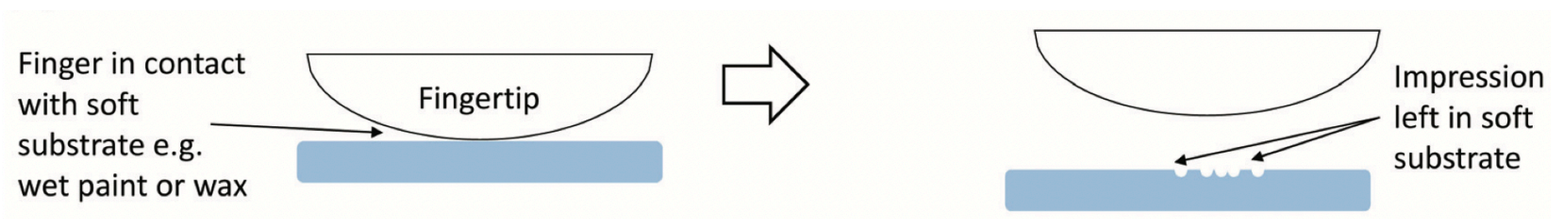
visible print

the finger deposits a visible material (blood, ink, etc.) onto a surface



plastic print

a fingerprint impressed in a soft surface (soap, putty, etc.)



Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

There are 3 types of fingerprints that can be found at a crime scene

latent print

made when body perspiration and/or oils are transferred to a surface
cannot be seen unless a chemical or physical process is performed

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

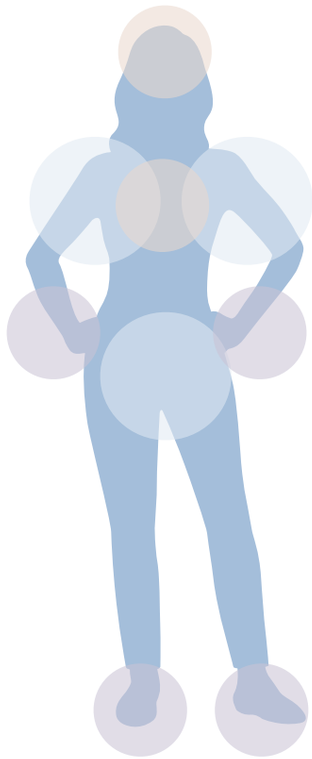
Quick review of oil secretions in the body: 3 types of glands responsible

sebaceous glands

primarily located on the
chest, back, and forehead

apocrine glands

concentrated in the groin,
arm pits, and perianal area



eccrine glands

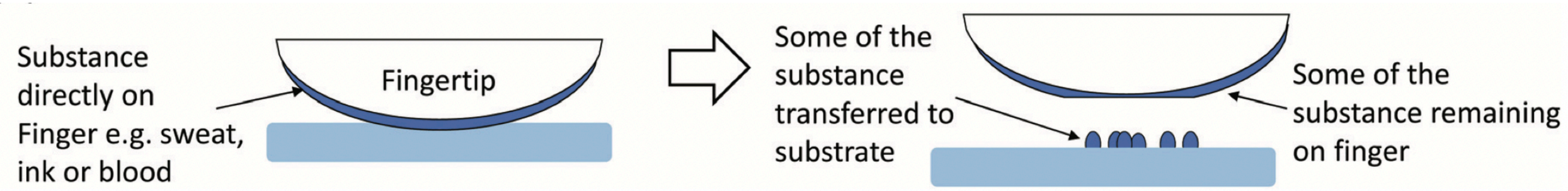
found all over the body,
but particularly numerous on the palms
of the hands and soles of the feet

most latent fingerprints also contain lipid material from the sebaceous glands due to contamination from touching the face, hair, etc.

therefore, eccrine gland secretions are the most important for fingerprinting

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis



a good quality latent fingerprint will generally contain ~1000ng of material

Source	*Inorganic constituents*	*Organic constituents*
Eccrine glands	Chloride	Amino acids
	Metal ions (Na^+, K^+, Ca^{2+})	Urea
		Uric acid
	Sulfate	Lactic acid
	Phosphate	Sugars
	Ammonia	Creatinine
	Water	Choline
Apocrine glands	Iron	Proteins
	Water	Carbohydrates
		Sterols
Sebaceous glands	–	Fatty acids
		Glycerides
		Hydrocarbons
		Alcohols

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

latent print: can't see with the naked eye → **Physical visualization** | **Chemical visualization**

Source	*Inorganic constituents*	*Organic constituents*
Eccrine glands	Chloride	Amino acids
	Metal ions (Na^+, K^+, Ca^{2+})	Urea
		Uric acid
	Sulfate	Lactic acid
	Phosphate	Sugars
	Ammonia	Creatinine
	Water	Choline
Apocrine glands	Iron	Proteins
	Water	Carbohydrates
		Sterols
Sebaceous glands	–	Fatty acids
		Glycerides
		Hydrocarbons
		Alcohols

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

Powder Fingerprinting

physical technique for visualization:
powdering

Chemical Fingerprinting

chemical technique for visualization:
ninhydrin, DFO

What are the advantages and disadvantages to each method?

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

Powder Fingerprinting

physical technique for visualization:
powdering

Chemical Fingerprinting

chemical technique for visualization:
ninhydrin, DFO

What are the advantages and disadvantages to each method?

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

Powder Fingerprinting

physical technique for visualization:
powdering

Types of Powder Fingerprinting

- traditional powder fingerprinting
- magnetic powder fingerprinting
- powder fingerprinting on wet surfaces

What are the advantages and disadvantages to each method?

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

there have been many formulas used for fingerprinting powder (graphite, metal oxides, sulfates, carbonates)

the most common chemical now is aluminum flake powder

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

there have been many formulas used for fingerprinting powder (graphite, metal oxides, sulfates, carbonates)

the most common chemical now is aluminum flake powder

- flat, plate-like structure of aluminum with each particle coated with a surface layer of stearic acid
- coats well to fingerprints, aluminum has a good hardness and reflectivity aids in photography and transfer of fingerprints
- a magnetic variant with iron mixed in can be a less destructive method of applying powder with a magnetic wand (no bristles come into contact with the fingerprint)

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

there have been many formulas used for fingerprinting powder (graphite, metal oxides, sulfates, carbonates)

10-20μm in diameter

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

there have been many formulas used for fingerprinting powder (graphite, metal oxides, sulfates, carbonates)

the most common chemical now is aluminum flake powder

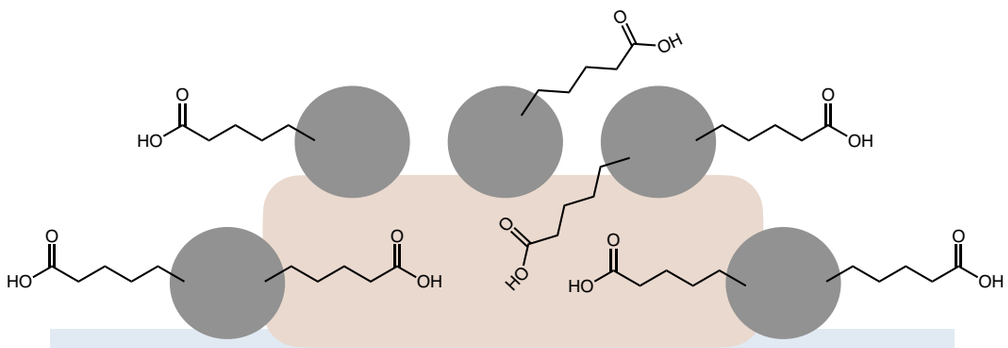
a ball-milling process is used to form the flakes from aluminum metal

10-20μm in diameter

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

there have been many formulas used for fingerprinting powder (graphite, metal oxides, sulfates, carbonates)



flat, plate-like structure of aluminum with each particle coated with a surface layer of stearic acid

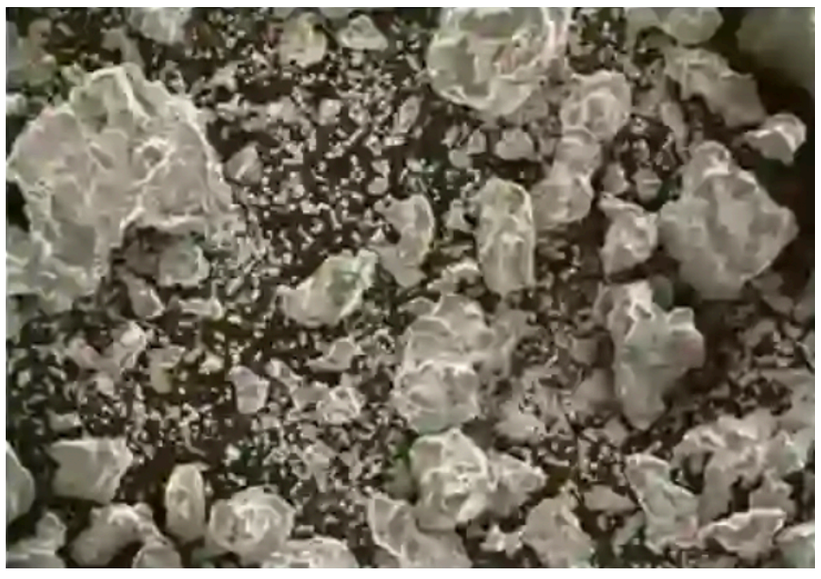
10-20μm in diameter

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

there have been many formulas used for fingerprinting powder (graphite, metal oxides, sulfates, carbonates)

granular powders are also used
iron added to make it magnetic



10-20μm in diameter

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

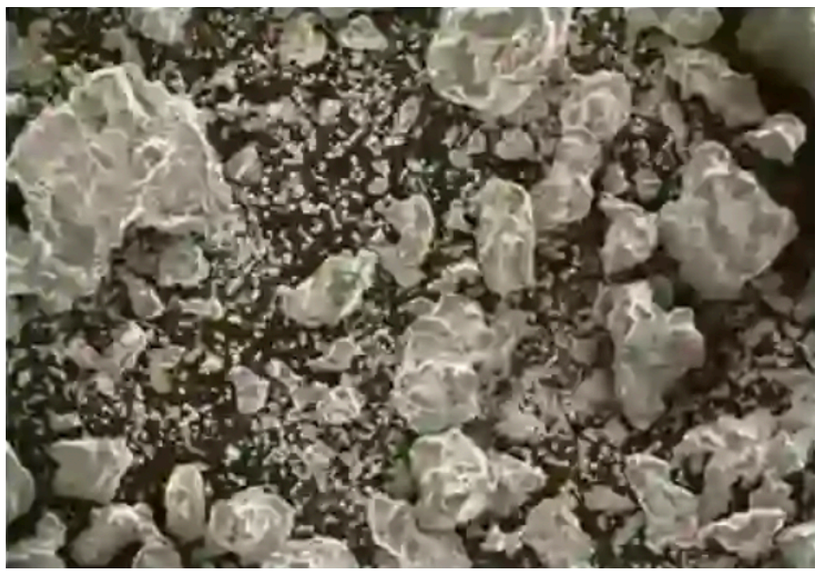
Fingerprint analysis

What are the advantages and disadvantages to each method?

coats well to fingerprints, aluminum has a good hardness and reflectivity aids in photography and transfer of fingerprints

the magnetic variant with iron mixed in can be a less destructive method of applying powder with a magnetic wand (no bristles come into contact with the fingerprint)

granular powders are also used
iron added to make it magnetic



10-20μm in diameter

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

What do we do if the surface is wet?

Traditional powder reagents certainly will not work

Fingerprint analysis

Small Particle reagent (SPR) is a method of wet powdering for wet, nonporous surfaces

- Small Particle reagent (SPR): prepared from powdered MoS_2 and an aqueous detergent
- the MoS_2 particles adhere to the greasy, water-insoluble components of the latent fingerprint
- other metal compounds such as Fe_2O_3 and $ZnCO_3$ have been employed

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

Powder Fingerprinting

physical technique for visualization:
powdering

Chemical Fingerprinting

chemical technique for visualization:
ninhydrin, DFO

What are the advantages and disadvantages to each method?

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

Powder Fingerprinting

physical technique for visualization:
powdering

Chemical Fingerprinting

chemical technique for visualization:
ninhydrin, DFO

What are the advantages and disadvantages to each method?

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Types of Chemical Fingerprinting

- cyanoacrylate fuming
- ninhydrin staining
- 1,8-diazafluoren-9-one (DFO) staining
- staining with physical developer (PD)

Chemical Fingerprinting

chemical technique for visualization:
ninhydrin, DFO

What are the advantages and disadvantages to each method?

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

cyanoacrylate vapor chamber

Cyanoacrylate Fuming

cyanoacrylate esters are colorless, monomeric liquids used in commercial adhesives, such as superglue

1) cyanoacrylate vapor formed by heating
2) polymerizes when it comes into contact with the moisture and alcohols present in latent fingerprint ridges

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

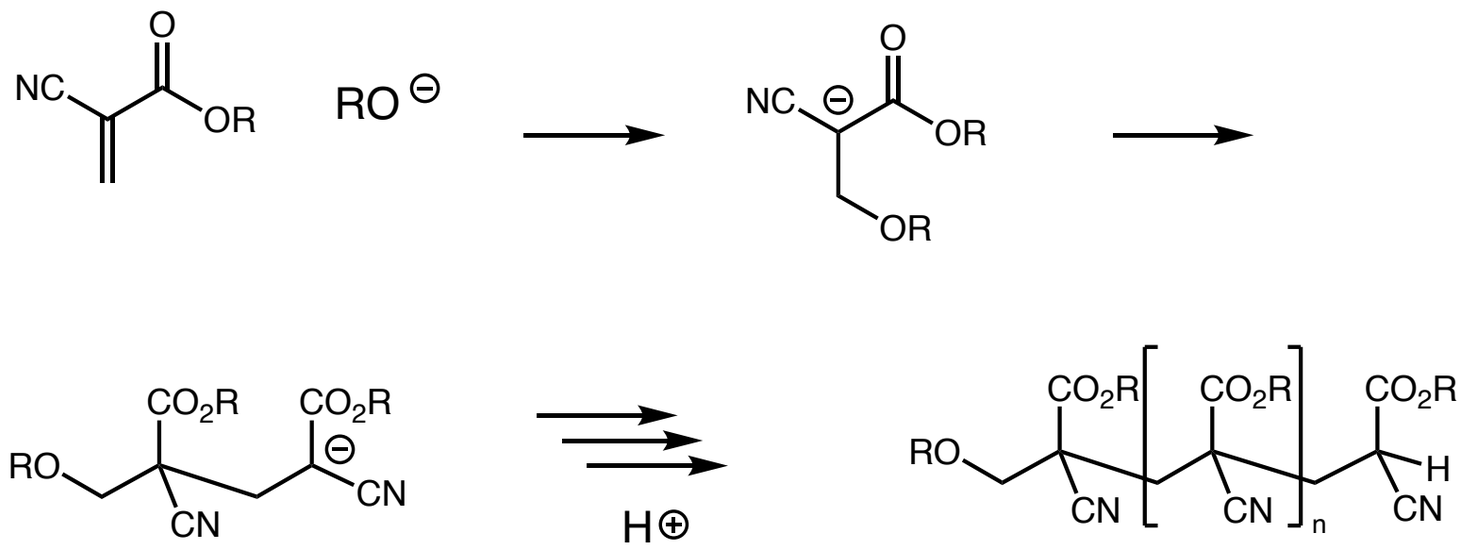
Fingerprint analysis

cyanoacrylate vapor chamber

Cyanoacrylate Fuming

cyanoacrylate esters are colorless, monomeric liquids used in commercial adhesives, such as superglue

Mechanism of Polymerization



Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

cyanoacrylate vapor chamber

Cyanoacrylate Fuming

cyanoacrylate esters are colorless, monomeric liquids used in commercial adhesives, such as superglue

Mechanism of Polymerization

- forms a hard, white polymer in the image of the fingerprint
- common on nonporous (glass, plastic, metal)

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

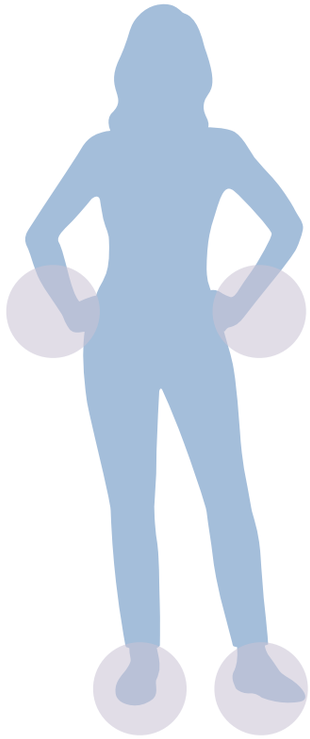
Fingerprint analysis

Fingerprints stained with ninhydrin

- weak marks or marks on dark surfaces may be hard to visualize
- very common for porous surfaces such as paper and cardboard

Ninhydrin Stain and Ruhemann's Purple

ninhydrin reacts with amino acids in the fingerprint secreted by the eccrine glands of the hands



eccrine glands

found all over the body,
but particularly numerous on the palms of the hands and soles of the feet

Can be used on fingermarks over 40 years of age!!

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

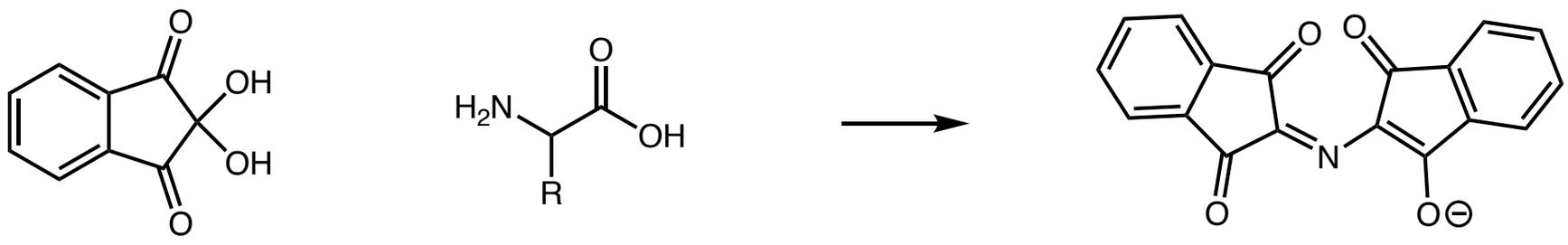
Fingerprint analysis

Fingerprints stained with ninhydrin

Ninhydrin Stain and Ruhemann's Purple

ninhydrin reacts with amino acids in the fingerprint secreted by the eccrine glands of the hands

produces a dark purple compound called Ruhemann's purple

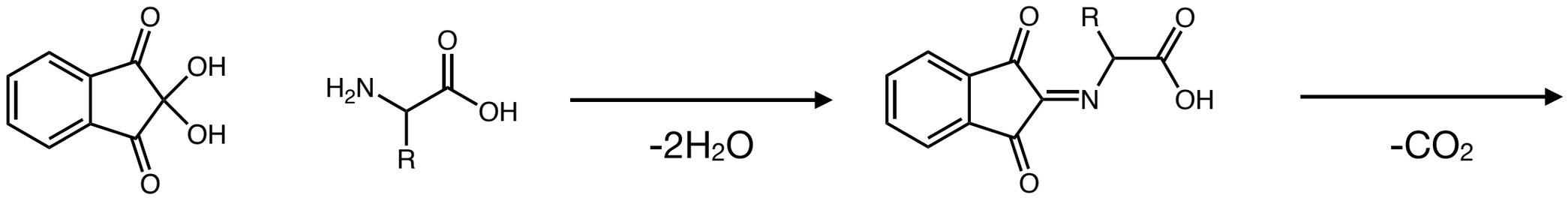


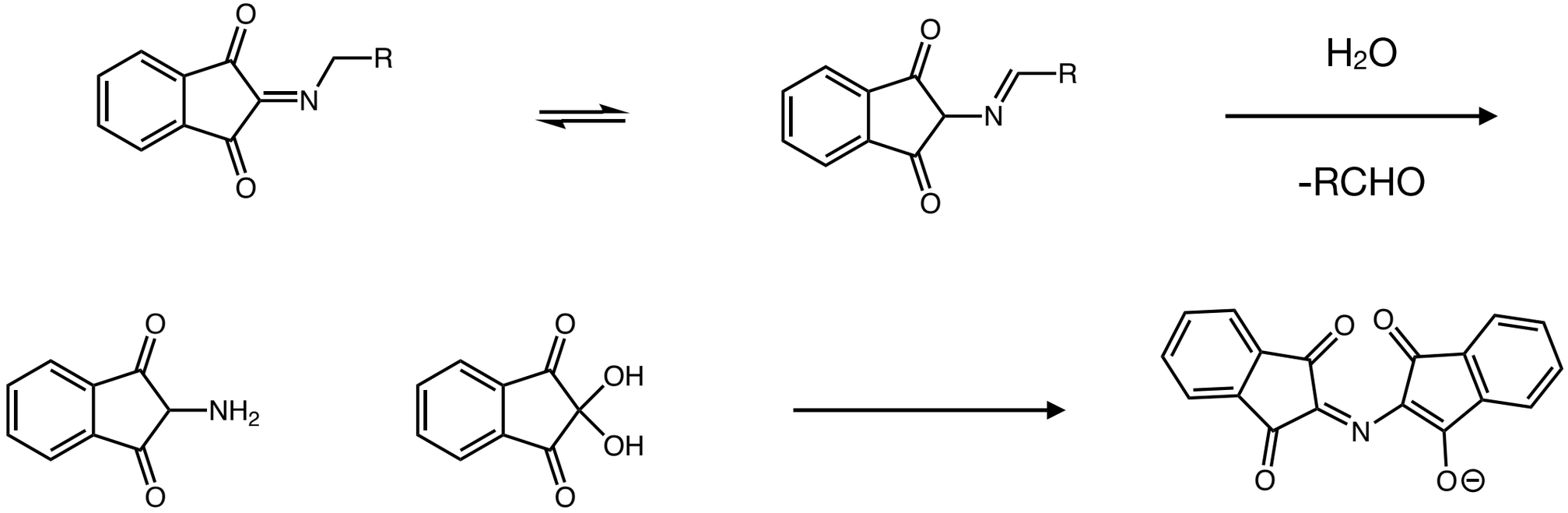
Ninhydrin amino acid **Ruhemann's purple**

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

Reaction Mechanism





Ruhemann's purple

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

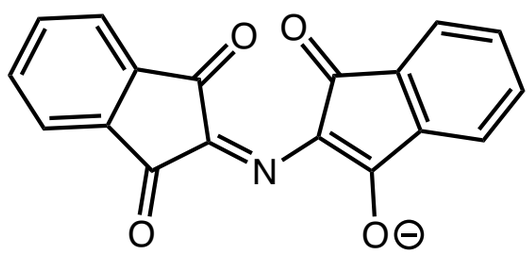
Zn and Cd complexes show good luminescence properties to enhance visualization!

Ninhydrin Stain and Ruhemann's Purple

---

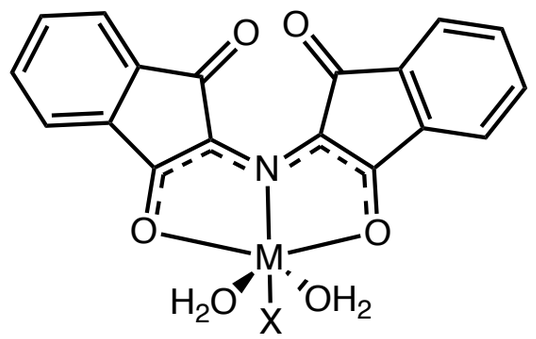
poor contrast for dark or colored surfaces

treatment with different salt solutions can produce differently colored fingerprints due to complexation of Ruhemann's purple with the metal ions



Ruhemann's purple

M=Zn, Cd, Mg
X=Cl, I, NO_3

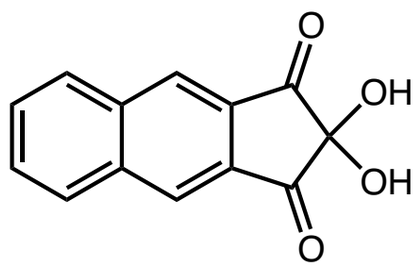


Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

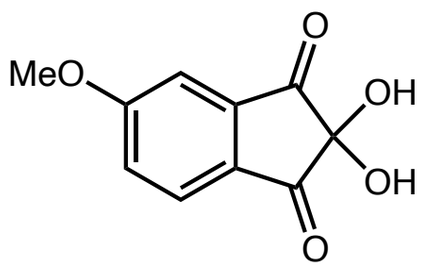
Fingerprint analysis

Ninhydrin Stain and Ruhemann's Purple

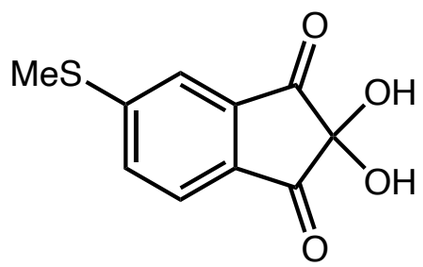
poor contrast for dark or colored surfaces



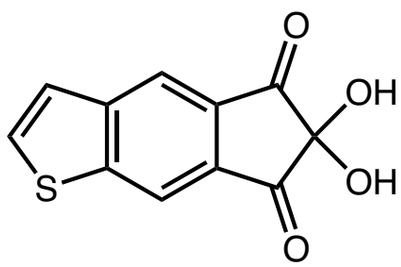
Benzo[*f*]ninhydrin



5-methoxyninhydrin



5-methylthioninhydrin



thieno[*f*]ninhydrin

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

Ninhydrin Stain and Ruhemann's Purple

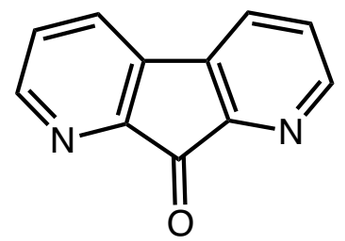
Pros:	*Cons:*
works well for paper and other porous materials	*contrast is poor with dark or colored materials*
metal additives can improve contrast	*cannot be used on surfaces that have been wet*

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

1,8-diazafluoren-9-one (DFO)

DFO reacts with amino acids in the fingerprint, but unlike ninhydrin, it must be heated for visualization



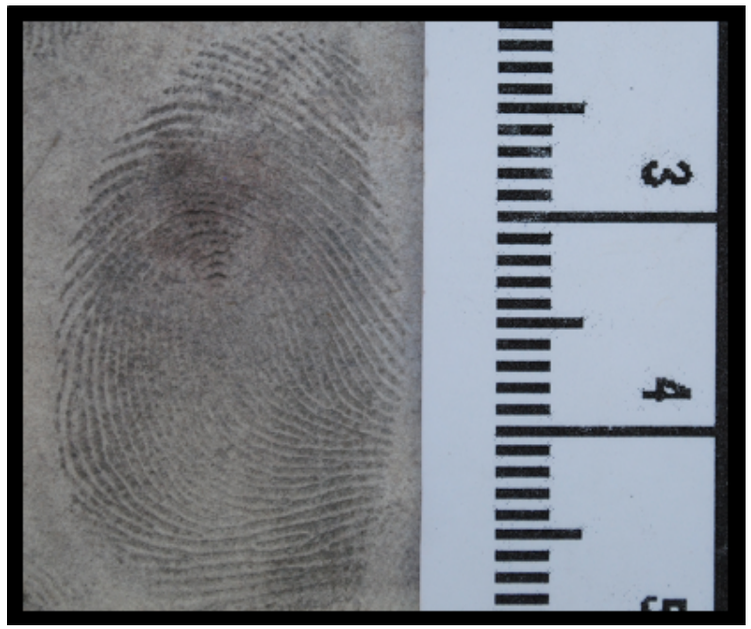
1,8-diazafluoren-9-one (DFO)

- developed marks are pale pink/purple and have strong luminescence

- DFO is considered to be the most sensitive commercial chemical reagent for detection of latent prints on paper

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis



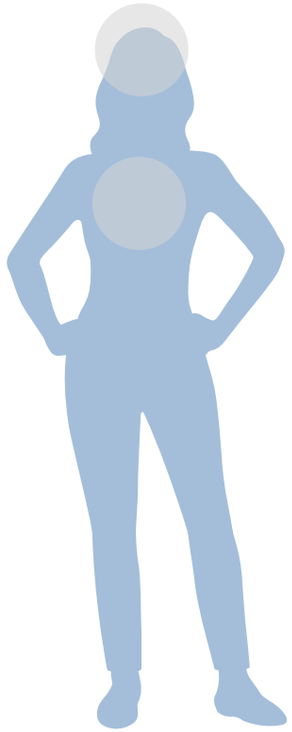
Fingerprints stained with physical developer

- It is effective even if the surface has been wet, contrary to methods that rely on amino acid detection, such as ninhydrin and DFO.

- prints appear as dark gray/ black as a result of silver metal deposition along the print ridges

Physical Developer

Physical Developer reacts to the sebaceous components of prints. It is good for visualization of prints on porous surfaces

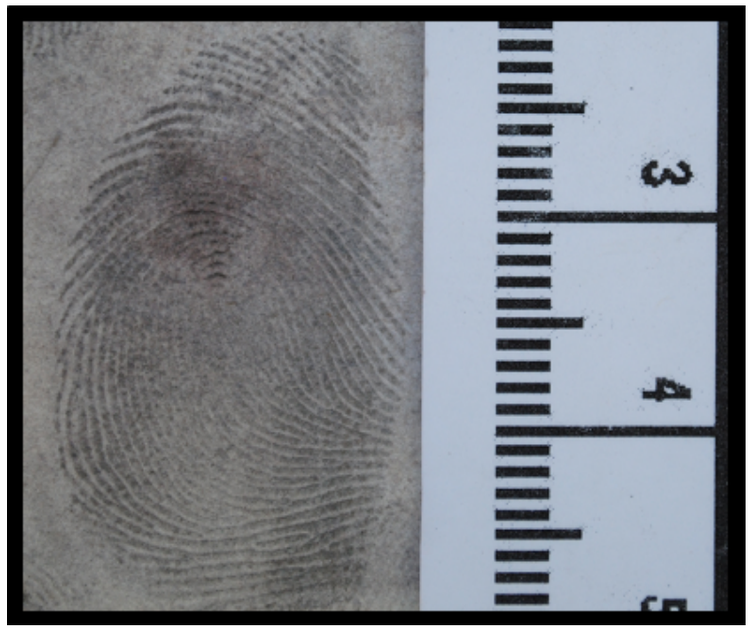


sebaceous glands

primarily located on the chest, back, and forehead

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis



Fingerprints stained with physical developer

Physical Developer (PD)

Physical Developer reacts to the sebaceous components of prints. It is good for visualization of prints on porous surfaces

Components of physical developer

- citric acid complexes with ferric ions and maintains a low pH

silver ions

$$Ag^{+} + Fe^{2+} \rightleftharpoons Ag^{0} + Fe^{3+}$$

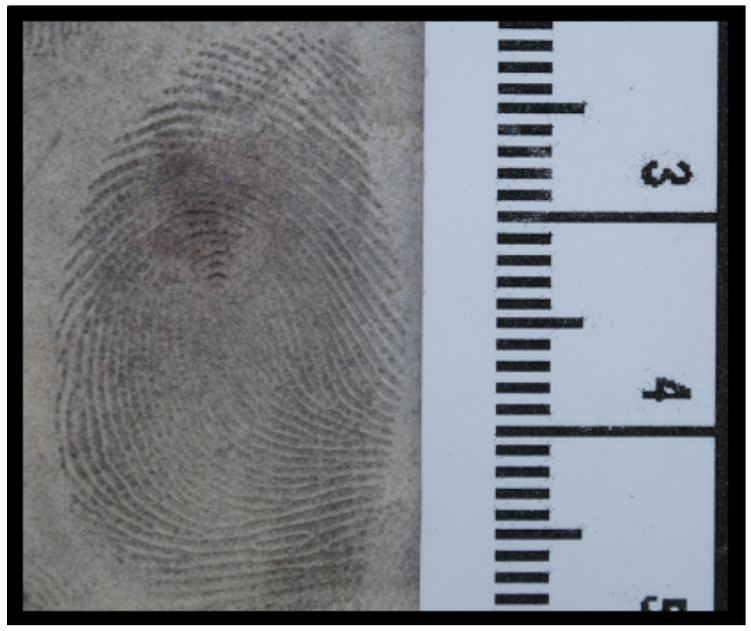
ferrous/ferric ions

citric acid buffer

n-dodecylamine (cationic surfactant)

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis



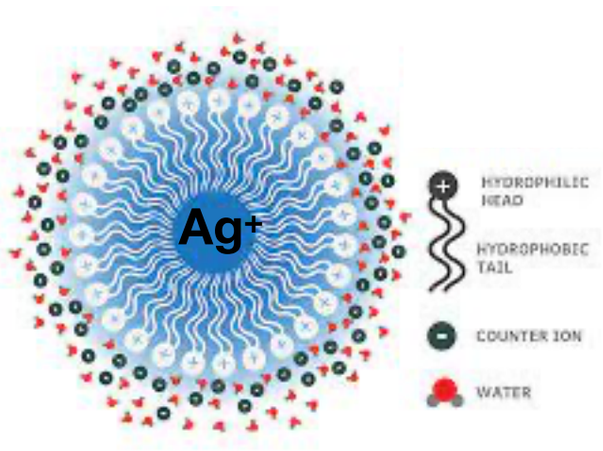
Fingerprints stained with physical developer

Physical Developer (PD)

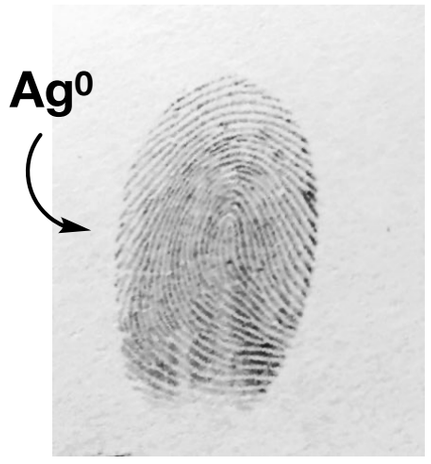
Physical Developer reacts to the sebaceous components of prints. It is good for visualization of prints on porous surfaces

Components of physical developer

sebaceous material in the fingerprint



silver ions contained in a micelle that prevent premature deposition onto the surface



micelles breaks down and the metallic silver is deposited onto the print ridges.

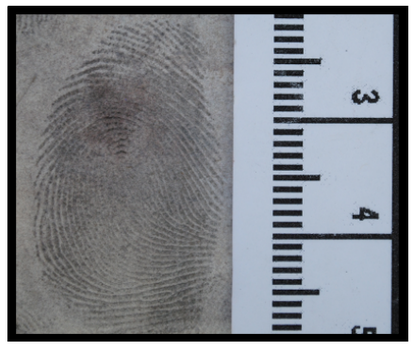
Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

compare and contrast visualization methods for latent fingerprints

Powdering: simple and low tech. Not incredibly sensitive, especially as prints age

SPR: not particularly sensitive, but good for wet objects that can't easily be removed from the crime scene and taken to a lab



PD: good for surfaces that have been wet, but solution is delicate to prepare and is unstable. Method is destructive

Cyanoacrylate Fuming: good form smooth, flat surfaces. Requires heating and sometimes vacuum deposition of metals

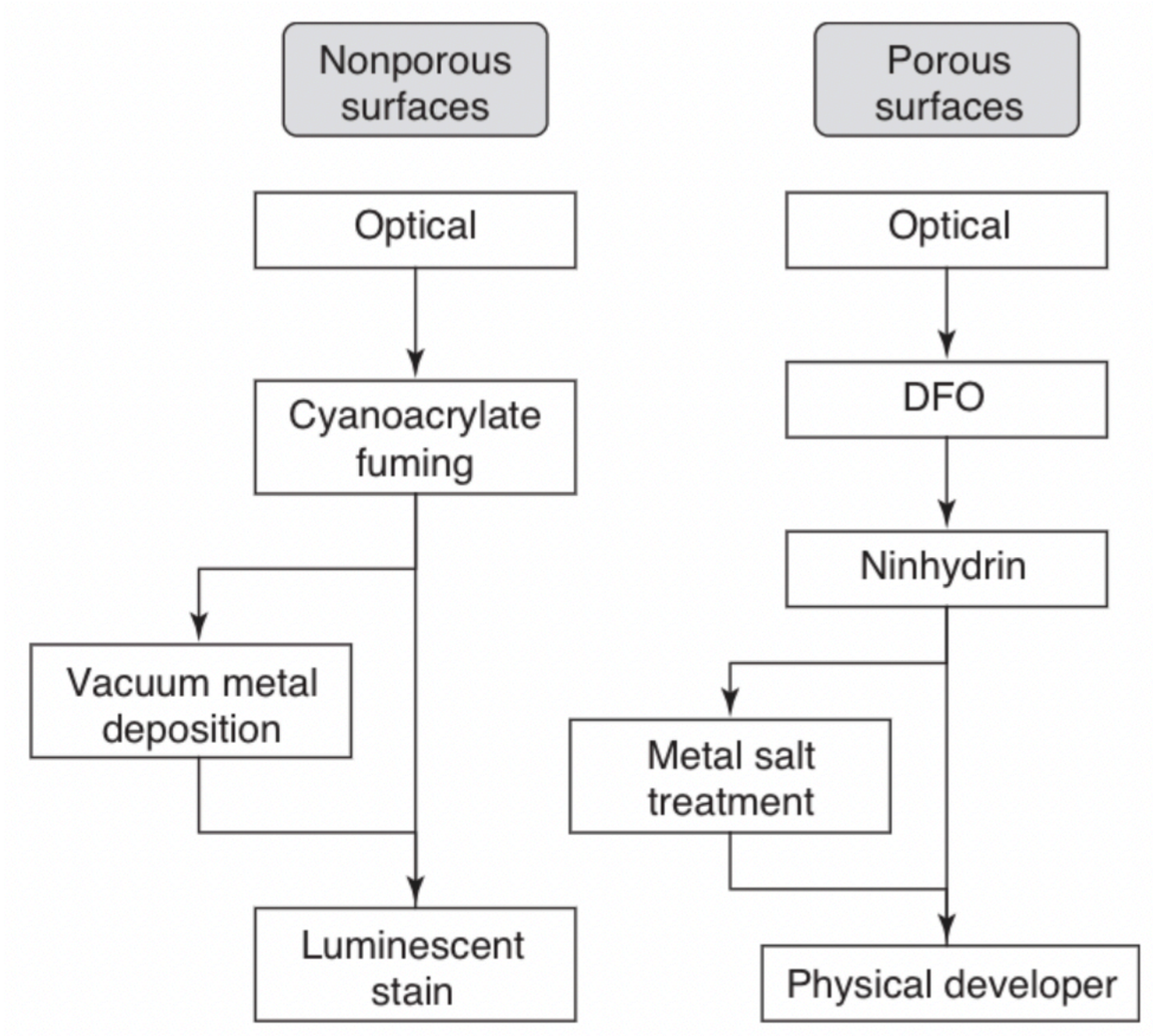
Ninhydrin: good for paper surfaces, not usable on surfaces that have been wet

DFO: most sensitive reagent for paper surfaces, not usable on surfaces that have been wet

Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Fingerprint analysis

Decision tree for particular substances



Lennard, C. (2005) *Forensic Sciences.* Elsevier Ltd.

Outline for the talk

- **Analytical Chemistry**
- **DNA in Forensic Science**
- **Fingerprinting**
- **Forensic Specialties**

Outline for the talk

- Analytical Chemistry
- DNA in Forensic Science
- Fingerprinting
- **Forensic Specialties**

Forensic science: beyond chemistry

Forensic Science

Social Sciences

Forensic Psychiatrists

Forensic Psychologists

Biological Sciences

Forensic pathology

Forensic anthropology

Forensic genetics

Bloodstain pattern analysis

Forensic entomology

Physical Sciences

Forensic chemistry

toxicology

fiber, soil, paint, glass, explosives analysis

fingerprint examination

Nobel Prize in Medicine/Physiology 2022

Svante Pääbo, 2022

“for his discoveries concerning the genomes of extinct hominids and human evolution.”